AD-A250 563

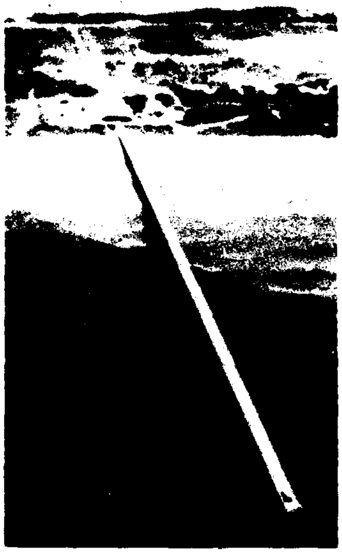
TECHNICAL REPORT CERC-92-3

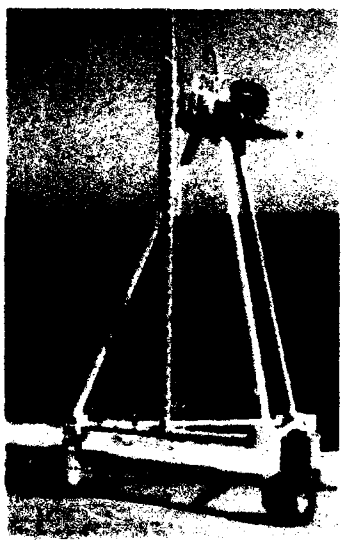
2

ANNUAL DATA SUMMARY FOR 1990 CERC FIELD RESEARCH FACILITY

Volume I

MAIN TEXT AND APPENDIXES A AND B





by

Michael W. Leffler, Clifford F. Baron, Brian L. Scarborough
Kent K. Hathaway, Ralph T. Hayes

Coastal Engineering Research Center

DEPARTMENT OF THE ARMY
Waterways Experiment Station, Corps of Engineers
3909 Halls Ferry Road, Vicksburg, Mississippi 39180-6199

April 1992

Final Report

Prepared for DEPARTMENT OF THE ARMY
US Army Corps of Engineers
Washington, DC 20314-1000

Under FRF Analysis Work Unit 32525

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. AGENCY USE ONLY *(Leave blank)*

2. REPORT DATE
April 1992

3. REPORT TYPE AND DATES COVERED
Final report in 2 volumes

4. TITLE AND SUBTITLE
Annual Data Summary for 1990 CERC Field Research Facility;
Volume I: Main Text and Appendixes A and B;
Volume II: Appendixes C Through E

5. FUNDING NUMBERS
WU 32525

6. AUTHOR(S)
Michael W. Leffler, Clifford F. Baron, Brian L. Scarborough
Kent K. Hathaway, Ralph T. Hayes

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
USAE Waterways Experiment Station
Coastal Engineering Research Center
3909 Halls Ferry Road, Vicksburg, MS 39180-6199

8. PERFORMING ORGANIZATION REPORT NUMBER
Technical Report
CERC-92-3

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)
US Army Corps of Engineers
Washington, DC 203 -1000

10. SPONSORING/MONITORING AGENCY REPORT NUMBER

11. SUPPLEMENTARY NOTES
See reverse.

12a. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution is unlimited.

12b. DISTRIBUTION CODE

13. ABSTRACT *(Maximum 200 words)*

This report provides basic data and summaries for the measurements made during 1990 at the US Army Engineer Waterways Experiment Station (WES), Coastal Engineering Research Center (CERC), Field Research Facility (FRF) in Duck, NC. The report includes comparisons of the 1990 data with cumulative statistics from 1980 to the present.

Summarized in this report are meteorological and oceanographic data, monthly bathymetric survey results, samples of quarterly aerial photography, and descriptions of 10 storms that occurred during the year. The year was highlighted by a severe storm in October. Waves with 5-m significant height were measured 1 km from shore.

This report is twelfth in a series of annual summaries of data collected at the FRF that began with Miscellaneous Report CERC-82-16, which summarizes data collected during 1977-1979. These reports are available from the WES Technical Report Distribution Section of the Information Technology Laboratory, Vicksburg, MS.

14. SUBJECT TERMS
See reverse.

15. NUMBER OF PAGES
I - 108; II - 87

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
UNCLASSIFIED	UNCLASSIFIED		

11. (Continued).

A limited number of copies of Volume II (Appendixes C through E) were published under a separate cover. Copies of Volume I (this report and Appendixes A and B) are available from National Technical Information Service, 5285 Port Royal Road, Springfield, VA 22161.

14. (continued).

Meteorologic research--statistics (LC)
Oceanographic reserch--statistics (LC)
Oceanographic research stations--North Carolina--Duck (LC)
Water waves--statistics (LC)

PREFACE

This report is the twelfth in a series of annual data summaries authorized by Headquarters, US Army Corps of Engineers (HQUSACE), under Civil Works Research Work Unit 32525, Field Research Facility Analysis, Coastal Flooding Program. Funds were provided through the US Army Engineer Waterways Experiment Station (WES), Coastal Engineering Research Center (CERC), under the program management of Ms. Carolyn M. Holmes, CERC. The HQUSACE Technical Monitors were Messrs. John H. Lockhart, Jr.; James E. Crews; John G. Housley; and Robert H. Campbell.

The data for the report were collected and analyzed at the WES/CERC Field Research Facility (FRF) in Duck, NC. The report was prepared by Mr. Michael W. Leffler, Computer Programmer Analyst, FRF, under the direct supervision of Mr. William A. Birkemeier, Chief, FRF Group, Engineering Development Division (EDD), and Mr. Thomas W. Richardson, Chief, EDD; and under the general supervision of Dr. James R. Houston and Mr. Charles C. Calhoun, Jr., Director and Assistant Director, CERC, respectively. Messrs. Kent K. Hathaway, Oceanographer, FRF, and Ralph T. Hayes, Electronics Technician, FRF, assisted with instrumentation. Mr. Brian L. Scarborough, Amphibious Vehicle Operator, FRF, assisted with data collection. Messrs. Clifford F. Baron, Stephen T. Blanchard, Matthew E. Cahur, and Mohsen Alhaddad and Mses. Wendy L. Smith and Juliana Atmadja assisted with data analysis at the FRF. The National Oceanic and Atmospheric Administration/ National Ocean Service maintained the tide gage and provided statistics for summarization.

Director of WES during the publication of this report was Dr. Robert W. Whalin. COL Leonard G. Hassell, EN, was Commander and Deputy Director.

CONTENTS

---

* A limited number of copies of Appendixes C-E (Volume II) were published under separate cover. Copies are available from National Technical Information Service, 5285 Port Royal Road, Springfield, Va 22161.

ANNUAL DATA SUMMARY FOR 1990

CERC FIELD RESEARCH FACILITY

PART I: INTRODUCTION

Background

1. The US Army Engineer Waterways Experiment Station (WES), Coastal Engineering Research Center's (CERC's) Field Research Facility (FRF), located on 0.7 km^2 at Duck, NC (Figure 1), consists of a 561-m-long research pier and accompanying office and field support buildings. The FRF is located near the middle of Currituck Spit along a 100-km unbroken stretch of shoreline extending south of Rudee Inlet, VA, to Oregon Inlet, NC. The FRF is bordered by the Atlantic Ocean to the east and Currituck Sound to the west. The Facility is designed to (a) provide a rigid platform from which waves, currents, water levels, and bottom elevations can be measured, especially during severe storms; (b) provide CERC with field experience and data to complement laboratory and analytical studies and numerical models; (c) provide a manned field facility for testing new instrumentation; and (d) serve as a permanent field base of operations for physical and biological studies of the site and adjacent region.

2. The research pier is a reinforced concrete structure supported on 0.9-m-diam steel piles spaced 12.2 m apart along the pier's length and 4.6 m apart across the width. The piles are embedded approximately 20 m below the ocean bottom. The pier deck is 6.1 m wide and extends from behind the duneline to about the 6-m water depth contour at a height of 7.8 m above the National Geodetic Vertical Datum (NGVD). The pilings are protected against sand abrasion by concrete erosion collars and against corrosion by a cathodic system.

3. An FRF Measurements and Analysis Program has been established to collect basic oceanographic and meteorological data at the site, reduce and analyze these data, and publish the results.

4. This report, which summarizes data for 1990, continues a series of reports begun in 1977.

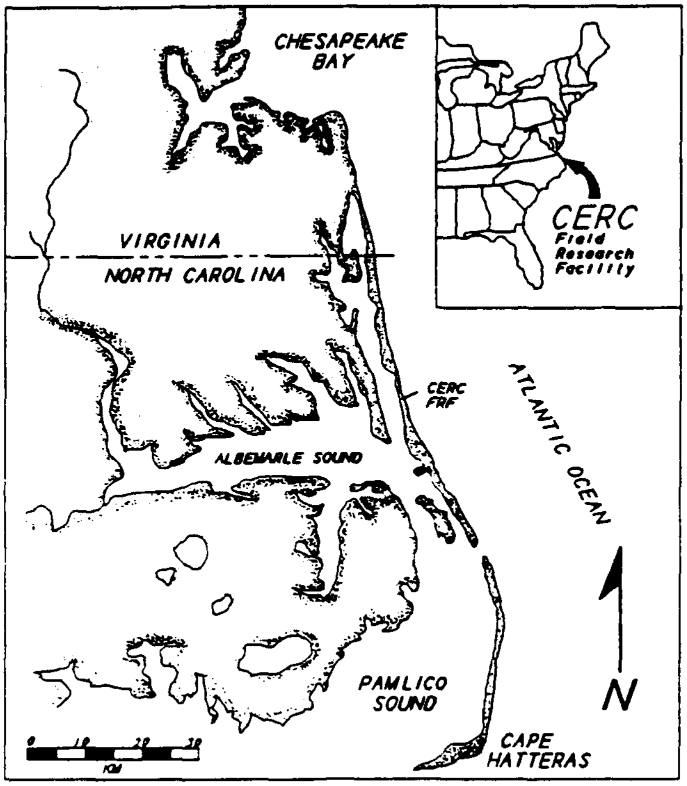


Figure 1. FRF location map

Organization of Report

5. This report is organized into nine parts and five appendixes. Part I is an introduction; Parts II through VIII discuss the various data collected during the year; and Part IX describes the storms that occurred. Appendix A presents the bathymetric surveys, Appendix B summarizes deepwater wave statistics, and Appendixes C through E (published under separate cover as Volume II) contain summary statistics for other gages.

6. In each part of this report, the respective instruments used for monitoring the meteorological or oceanographic conditions are briefly described along with data collection and analysis procedures and data results. The instruments were interfaced with the primary data acquisition system, a Digital Equipment Corporation (Maynard, MA) VAX-11/750 minicomputer located in the FRF laboratory building. More detailed explanations of the design and the operation of the instruments may be found in Miller (1980). Readers' comments on the format and usefulness of the data presented are encouraged.

Availability of Data

7. Table 1 summarizes the available data. In addition to the wave data summaries in the main text, more extensive summaries for each of the wave gages are provided in Appendixes B through E.

Table 1

1990 Data Availability

	Gage	Jan					Feb				Mar				Apr					May				Jun				Jul					Aug				Sep				Oct					Nov				Dec			
	ID	1	2	3	4	5	1	2	3	4	1	2	3	4	1	2	3	4	5	1	2	3	4	1	2	3	4	1	2	3	4	5	1	2	3	4	1	2	3	4	1	2	3	4	5	1	2	3	4	1	2	3	4
Weather																																																					
Anemometer	932	*	*	*	*	*	*	*	*	*	/	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	/	*	*	/	/	*	*	*	*	*	*	*	*	*	*	*	*	*	/	*	*	*	*	*	*	*	*
Atmospheric Pres.	616	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	/	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	/	*	*	*	*	*	*	*	*
Air Temperature	624	*	*	*	*	*	*	*	*	*	/	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	/	*	*	*	*	*	*	*	*	*	*	*	*	-	*	*	*	*	/	*	*	*	*	*	*	*	*
Precipitation	604	-	-	-	-	-	-	-	-	-	-	-	/	*	*	*	*	*	*	*	*	*	*	*	*	*	/	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	/	*	*	*	*	*	*	*	*
Waves																																																					
Offshore Waverider	630	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	/	*	*	*	/	*	*	*	*	*	*	*	*	*	*	*	*	*	/	*	*	/	/	*	*	*	*
Pressure Gage	111	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	/	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	/	*	*	*	*	*	*	*	*
Pier End	625	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	/	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	/	*	*	*	*	*	*	*	*
Pier Nearshore	645	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	/	*	*	*	*	*	*	*	*	/	/	*	*	*	*	*	*	*	/	*	*	*	*	*	*	*	*
Currents																																																					
Pier End		*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
Pier Nearshore		*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
Beach		*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	/	/	/	*	*	*	*	*	*	*	*
Pier End Tide Gage		*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
Water Characteristics																																																					
Temperat e		*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
Visibility		*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
Density		*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
Bathymetric Surveys						*			*				*							*						*									*							*											
Photography																																																					
Beach		*	*	*	/	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	/	-	-	/	*	*	*	*	*	*	*	*	*	*	/	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
Aerial					*																																																

Notes: * Full week of data obtained.
/ Less than 7 days of data obtained.
- No data obtained.

8. The annual data summary herein summarizes daily observations by month and year to provide basic data for analysis by users. Daily measurements and observations have already been reported in a series of monthly Preliminary Data Summaries (FRF 1990). If individual data for the present year are needed, the user can obtain detailed information (as well as the monthly and previous annual reports) from the following address:

USAE Waterways Experiment Station
Coastal Engineering Research Center
Field Research Facility
1261 Duck Rd.
Kitty Hawk, NC 27949-9440

Although the data collected at the FRF are designed primarily to support ongoing CERC research, use of the data by others is encouraged. The WES/CERC Coastal Engineering Information and Analysis Center (CEIAC) is responsible for storing and disseminating most of the data collected at the FRF. All data requests should be in writing and addressed to:

Commander and Director
US Army Engineer Waterways Experiment Station
ATTN: Coastal Engineering Information Analysis Center
3909 Halls Ferry Road
Vicksburg, MS 39180-6199

Tidal data other than the summaries in this report can be obtained directly from the following address:

National Oceanic and Atmospheric Administration
National Ocean Service
ATTN: Tide Analysis Branch
Rockville, MD 20852

A complete explanation of the exact data desired for specific dates and times will expedite filling any request; an explanation of how the data will be used will help CEIAC or the National Oceanic and Atmospheric Administration (NOAA)/National Ocean Service (NOS) determine if other relevant data are available. For information regarding the availability of data for all years, contact CEIAC at (601) 634-2012. Costs for collecting, copying, and mailing will be borne by the requester.

PART II: METEOROLOGY

9. This section summarizes the meteorological measurements made during the current year and in combination with all previous years. Meteorological measurements during storms are given in Part IX.

10. Mean air temperature, atmospheric pressure, and wind speed and direction were computed for each data file, which consisted of data sampled two times per second for 34 min every 6 hr beginning at or about 0100, 0700, 1300, and 1900 eastern standard time (EST); these hours correspond to the time that the National Weather Service (NWS) creates daily synoptic weather maps. During storms, data recordings were made more frequently. The data are summarized in Table 2.

Table 2

Meteorological Statistics

	Mean Air Temperature deg C		Mean Atmospheric Pres. mb		Precipitation, mm				Wind Resultants			
					1990	1978-1990			1990		1980-1990	
Month	1990	1983-1990	1990	1983-1990	Total	Mean	Maxima	Minima	Speed m/sec	Direction deg	Speed m/sec	Direction deg
Jan	8.0	5.8	1016.9	1017.8	118	98	180	44	2.4	239	2.3	332
Feb	10.2	6.6	1019.3	1017.6	68	75	113	20	1.4	248	1.7	346
Mar	11.3	9.5	1020.8	1016.7	114	93	206	35	0.7	27	1.5	2
Apr	13.9	13.5	1016.0	1013.6	136	99	182	0	0.4	10	0.3	328
May	18.9	18.8	1012.9	1015.8	189	76	239	20	1.4	216	0.5	193
Jun	22.7	23.4	1014.2	1015.4	136	88	136	27	1.2	232	1.1	201
Jul	26.1	26.0	1014.8	1016.3	32	95	275	19	2.9	187	1.8	209
Aug	25.5	25.9	1014.1	1016.1	63	98	221	30	0.3	43	0.5	92
Sep	22.5	22.4	1015.1	1017.6	20	83	226	5	1.5	15	2.0	39
Oct	20.3	17.8	1015.7	1019.3	73	65	143	17	1.1	52	2.3	27
Nov	12.7	13.2	1017.3	1018.2	54	90	145	26	2.1	285	1.7	346
Dec	10.7	7.9	1019.6	1019.5	57	66	131	4	1.1	313	2.2	332
Average	16.9	15.9	1016.4	1017.0	88	85			0.5	257	0.8	354
Total					1060	1026						

Air Temperature

11. The FRF enjoys a typical marine climate that moderates the temperature extremes of both summer and winter.

Measurement instruments

12. A Yellow Springs Instrument Company, Inc. (YSI) (Yellow Springs, OH), electronic temperature probe with analog output interfaced to the FRF's computer was operated beside the NWS's meteorological instrument shelter located 43 m behind the dune (Figure 2). To ensure proper temperature

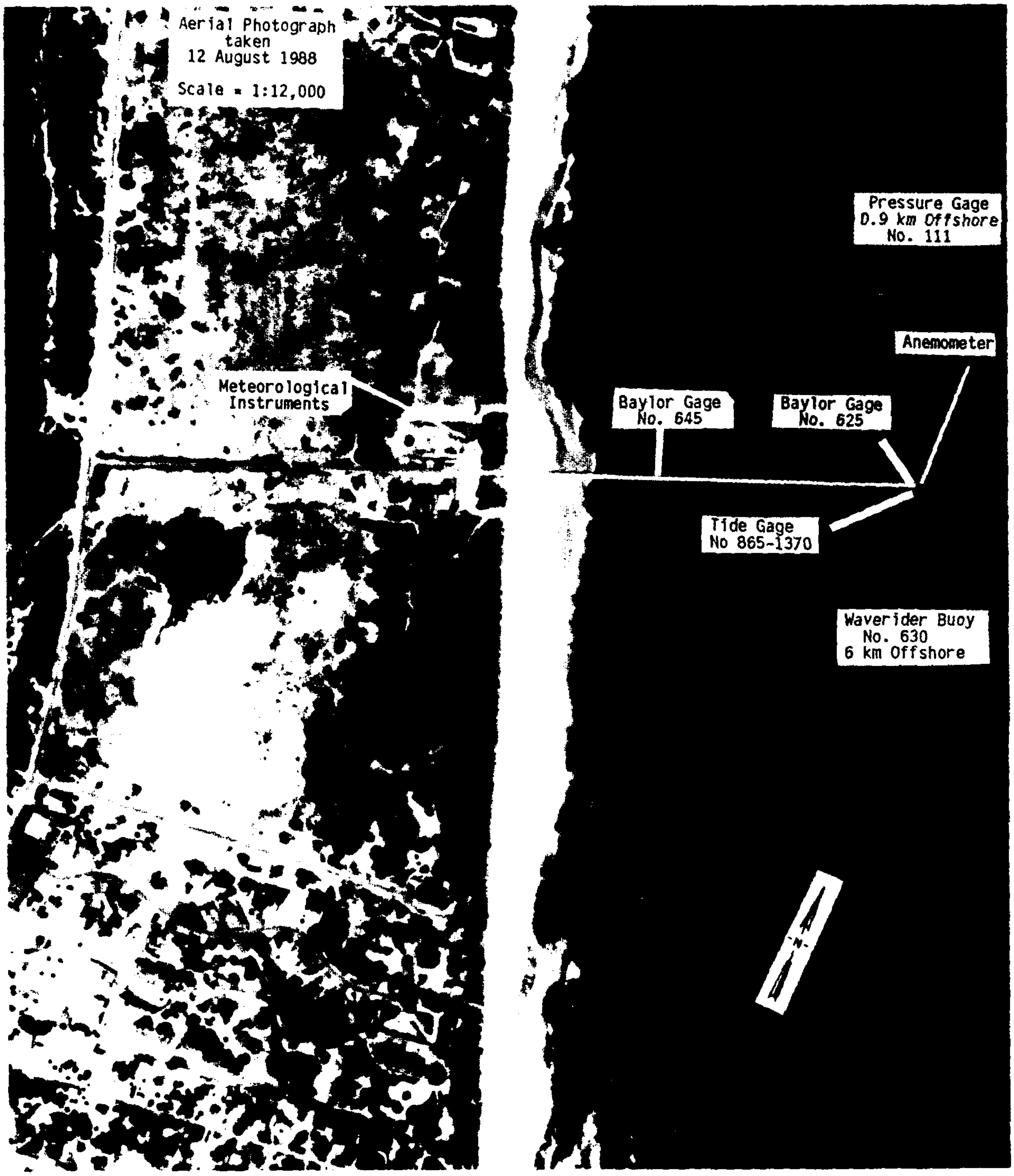


Figure 2. FRF gage locations

readings, the probe was installed 3 m aboveground inside a "coolie hat" to shade it from direct sun, yet provide proper ventilation.

Results

13. Daily and average air temperature values are tabulated in Table 2 and shown in Figure 3.

Atmospheric Pressure

Measurement instruments

14. Electronic atmospheric pressure sensor. Atmospheric pressure was measured with a YSI electronic sensor with analog output located in the laboratory building at 9 m above NGVD. Data were recorded on the FRF computer. Data from this gage were compared with those from an NWS aneroid barometer to ensure proper operation.

15. Microbarograph. A Weathertronics, Incorporated (Sacramento, CA), recording aneroid sensor (microbarograph) located in the laboratory building also was used to continuously record atmospheric pressure variation.

16. The microbarograph was compared daily with the NWS aneroid barometer, and adjustments were made as necessary. Maintenance of the microbarograph consisted of inking the pen, changing the chart paper, and winding the clock every 7 days. During the summer, a meteorologist from the NWS checked and verified the operation of the barometer.

17. The microbarograph was read and inspected daily using the following procedure:

a. The pen was zeroed (where applicable).

b. The chart time was checked and corrected, if necessary.

c. Daily reading was marked on the chart for reference.

d. The starting and ending chart times were recorded, as necessary.

e. New charts were installed when needed.

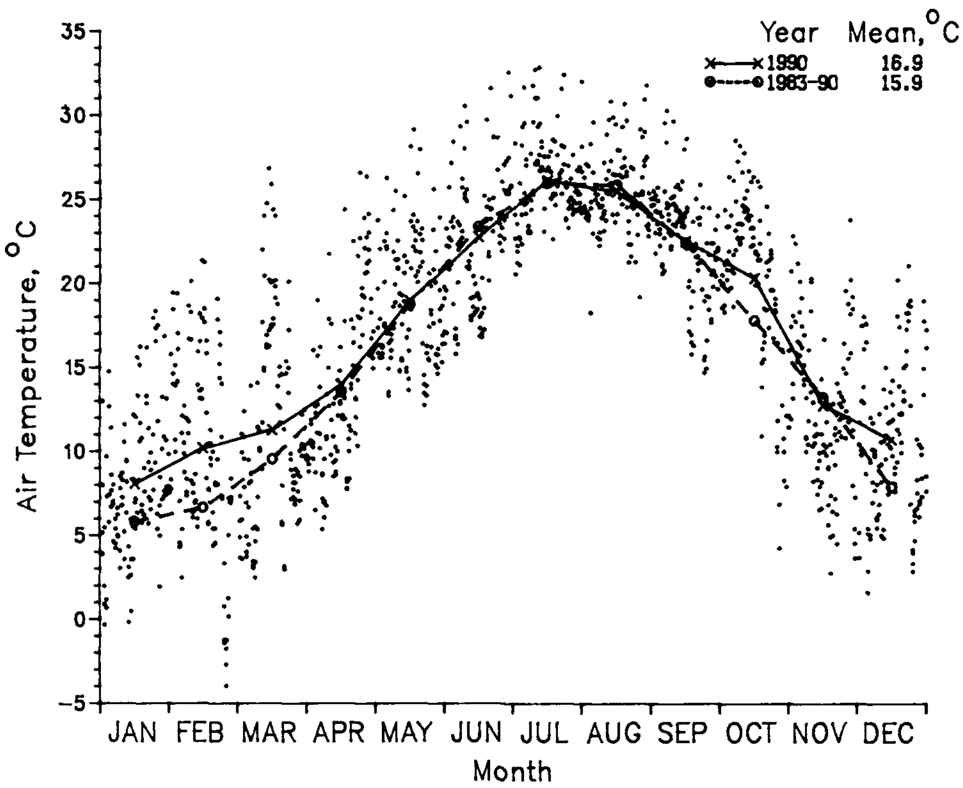


Figure 3. Daily air temperature values with monthly means

Results

18. Daily and average atmospheric pressure values are presented in Figure 4, and summary statistics are presented in Table 2.

Precipitation

19. Precipitation is generally well distributed throughout the year. Precipitation from midlatitude cyclones (northeasters) predominates in the winter, whereas local convection (thunderstorms) accounts for most of the summer rainfall.

Measurement instruments

20. Electronic rain gage. A Belfort Instrument Company (Baltimore, MD) 30-cm weighing rain gage, located near the instrument shelter 47 m behind the dune, measured daily precipitation. According to the manufacturer, the instrument's accuracy was 0.5 percent for precipitation amounts less than

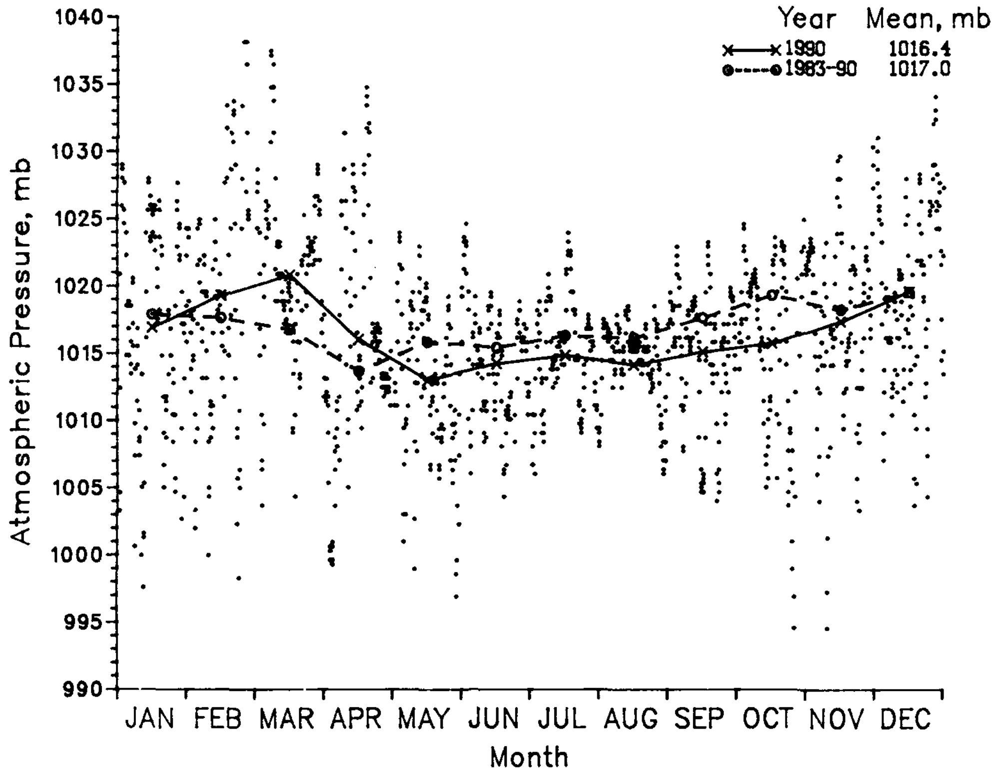


Figure 4. Daily barometric pressure values with monthly means

15 cm and 1.0 percent for amounts greater than 15 cm.

21. The rain gage was inspected daily, and the analog chart recorder was maintained by procedures similar to those for the microbarograph.

22. Plastic rain gage. An Edwards Manufacturing Company (Alberta Lea, MN) True Check 15-cm-capacity clear plastic rain gage with a 0.025-cm resolution was used to monitor the performance of the weighing rain gage. This gage, located near the weighing gage, was compared daily; and very few discrepancies were identified during the year.

Results

23. Daily and monthly average precipitation values are shown in Figure 5. Statistics of total precipitation for each month during this year and average totals for all years combined are presented in Table 2.

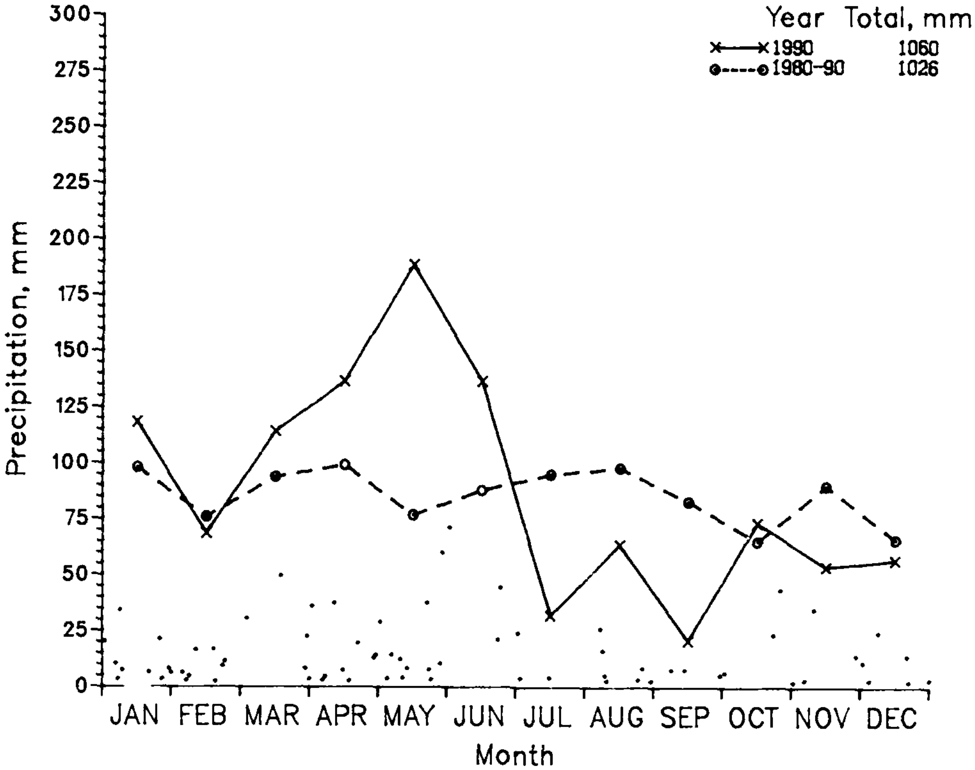


Figure 5. Daily precipitation values with monthly totals

Wind Speed and Direction

24. Winds at the FRF are dominated by tropical maritime air masses that create low to moderate, warm southern breezes; arctic and polar air masses that produce cold winds from northerly directions; and smaller scale cyclonic, low pressure systems, which originate either in the tropics (and move north along the coast) or on land (and move eastward offshore). The dominant wind direction changes with the season, being generally from northern directions in the fall and winter and from southern directions in the spring and summer. It is common for fall and winter storms (northeasters) to produce winds with average speeds in excess of 15 m/sec.

Measurement instrument

25. Winds were measured at the seaward end of the pier at an elevation of 19.1 m (Figure 2) using a Weather Measure Corporation (Sacramento, CA) Skyvane Model W102P anemometer. Wind speed and direction data were collected on the FRF computer. The anemometer manufacturer specifies an accuracy of ± 0.45 m/sec below 13 m/sec and 3 percent at speeds above 13 m/sec, with a

threshold of 0.9 m/sec. Wind direction accuracy is ± 2 deg with a resolution of less than 1 deg. The anemometer is calibrated annually at the National Bureau of Standards in Gaithersburg, MD, and is within the manufacturer's specifications.

Results

26. Annual and monthly joint probability distributions of wind speed versus direction were computed. Winds speeds were resolved into 3-m/sec intervals, whereas the directions were at 22.5-deg intervals (i.e. 16-point compass direction specifications). These distributions are presented as wind "roses," such that the length of the petal represents the frequency of occurrence of wind blowing from the specified direction, and the width of the petal is indicative of the speed. Resultant directions and speeds were also determined by vector averaging the data (see Table 2). Wind statistics are presented in Figures 6, 7, and 8.

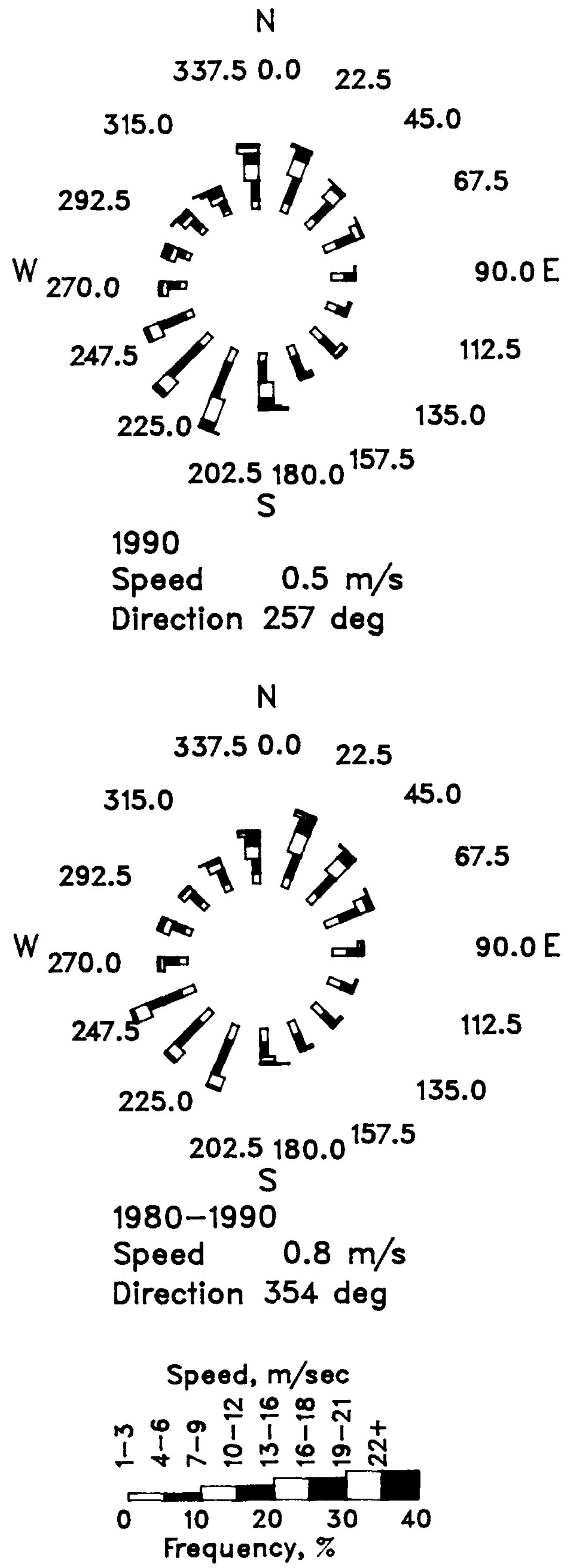


Figure 6. Annual wind roses

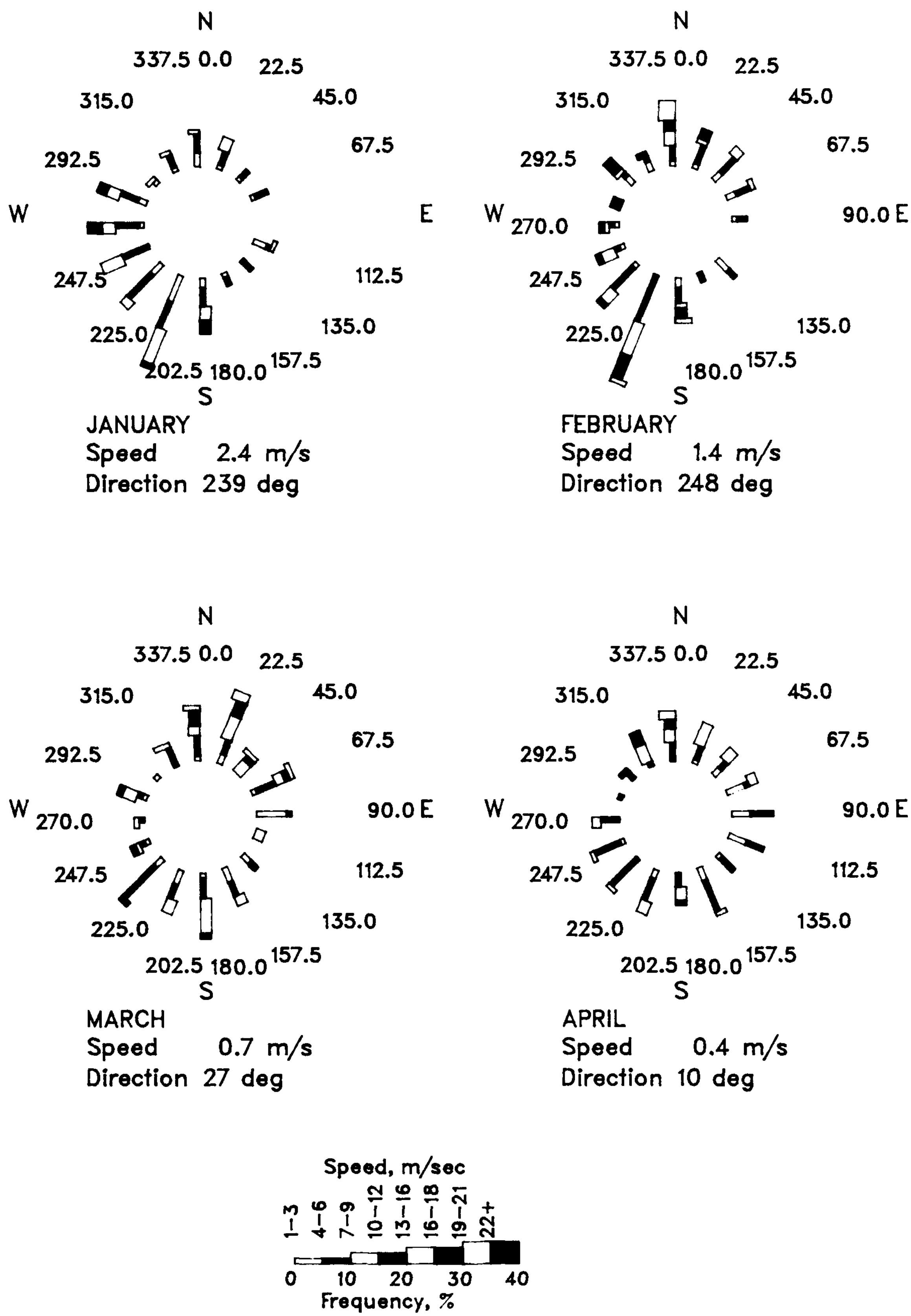


Figure 7. Monthly wind roses for 1990
(Sheet 1 of 3)

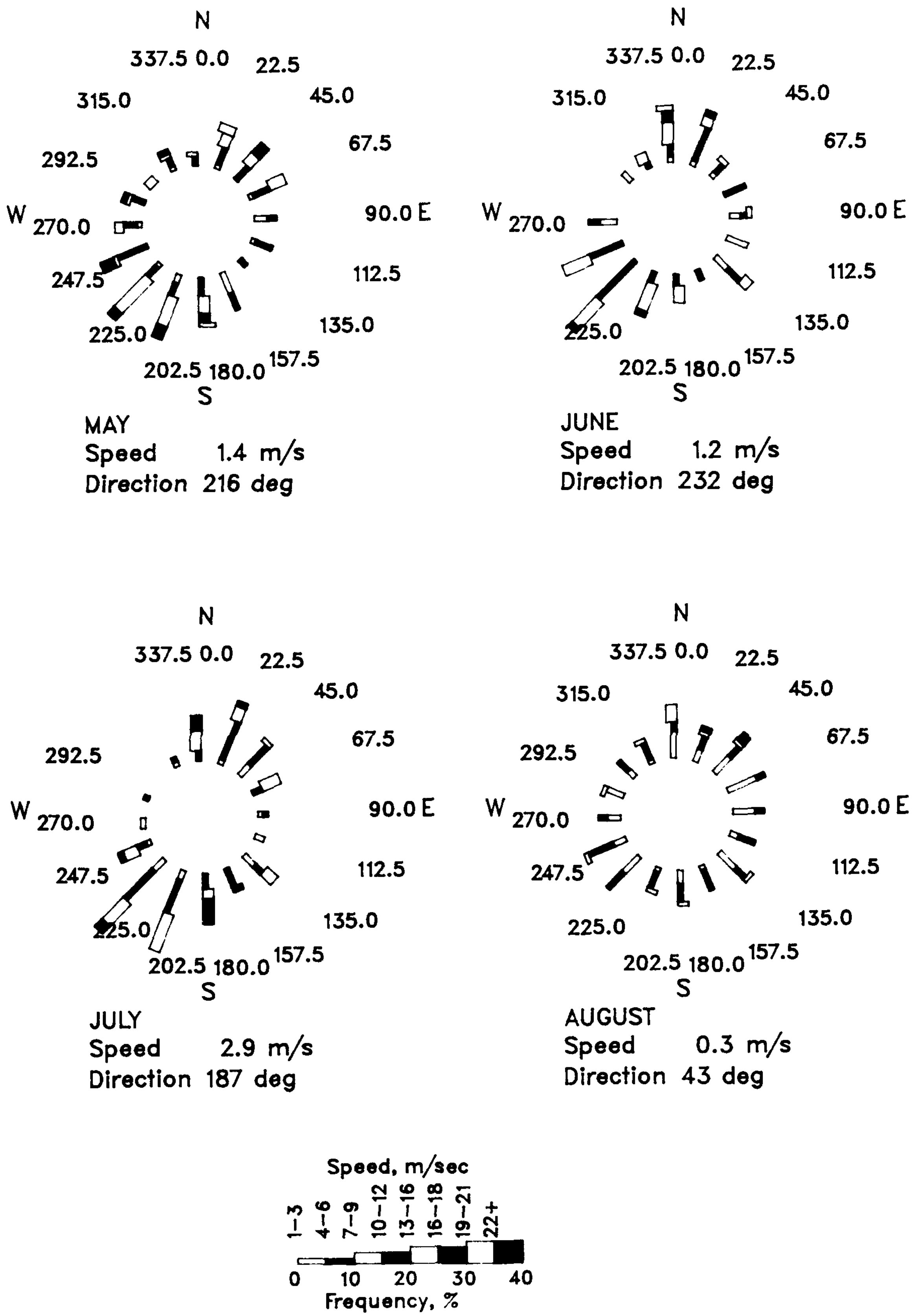


Figure 7. (Sheet 2 of 3)

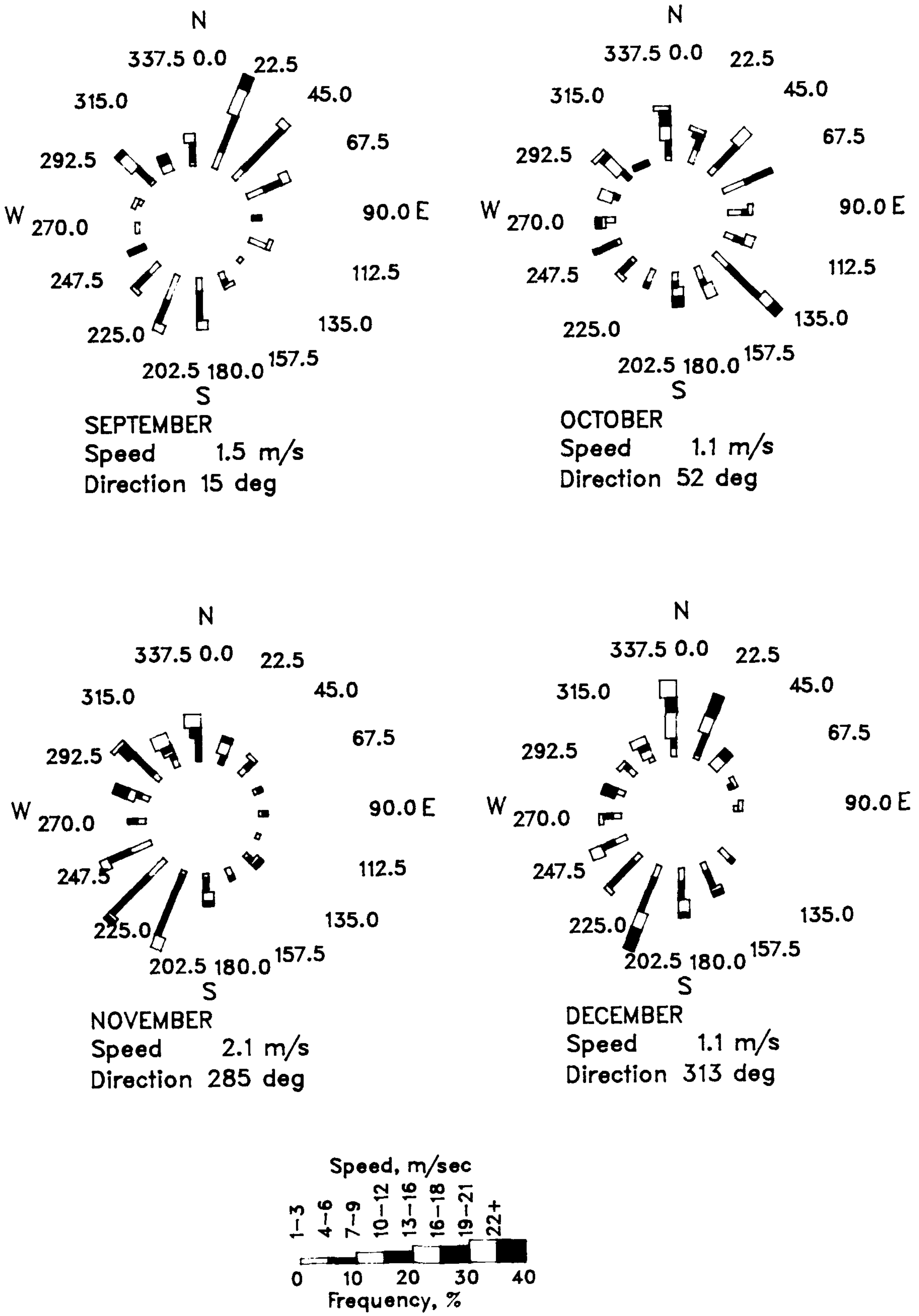


Figure 7. (Sheet 3 of 3)

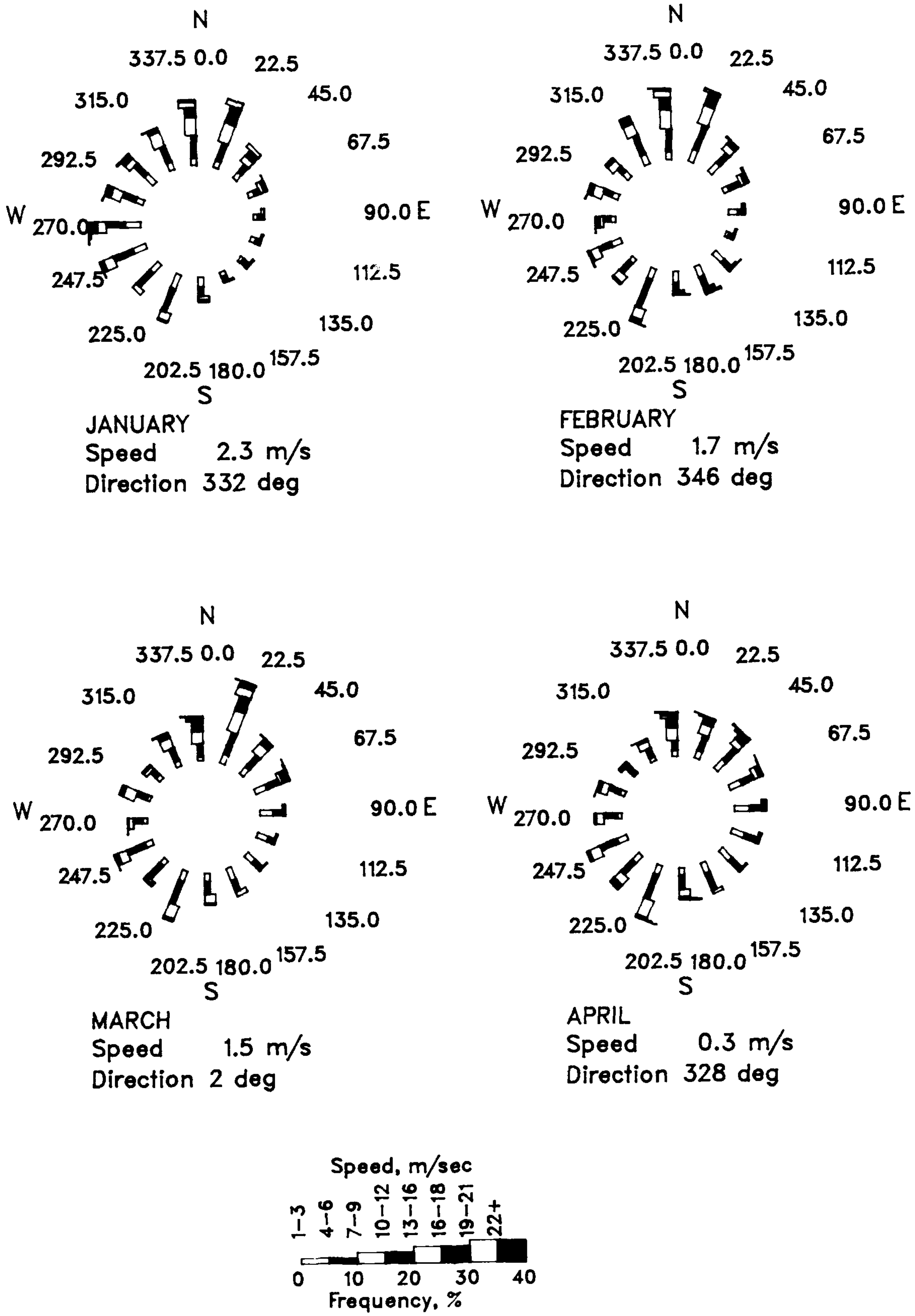


Figure 8. Monthly wind roses for 1980 through 1990 (Sheet 1 of 3)

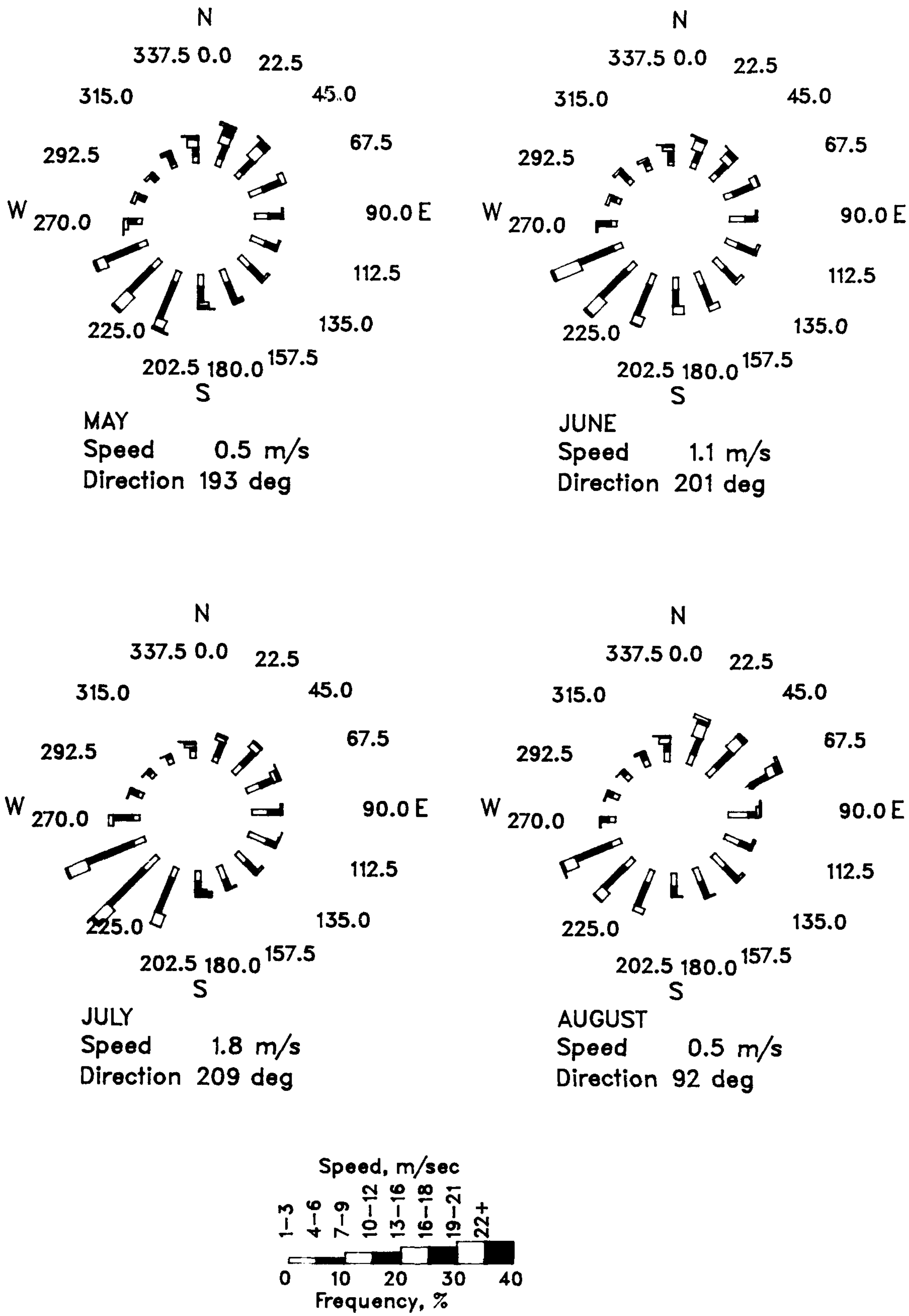


Figure 8. (Sheet 2 of 3)

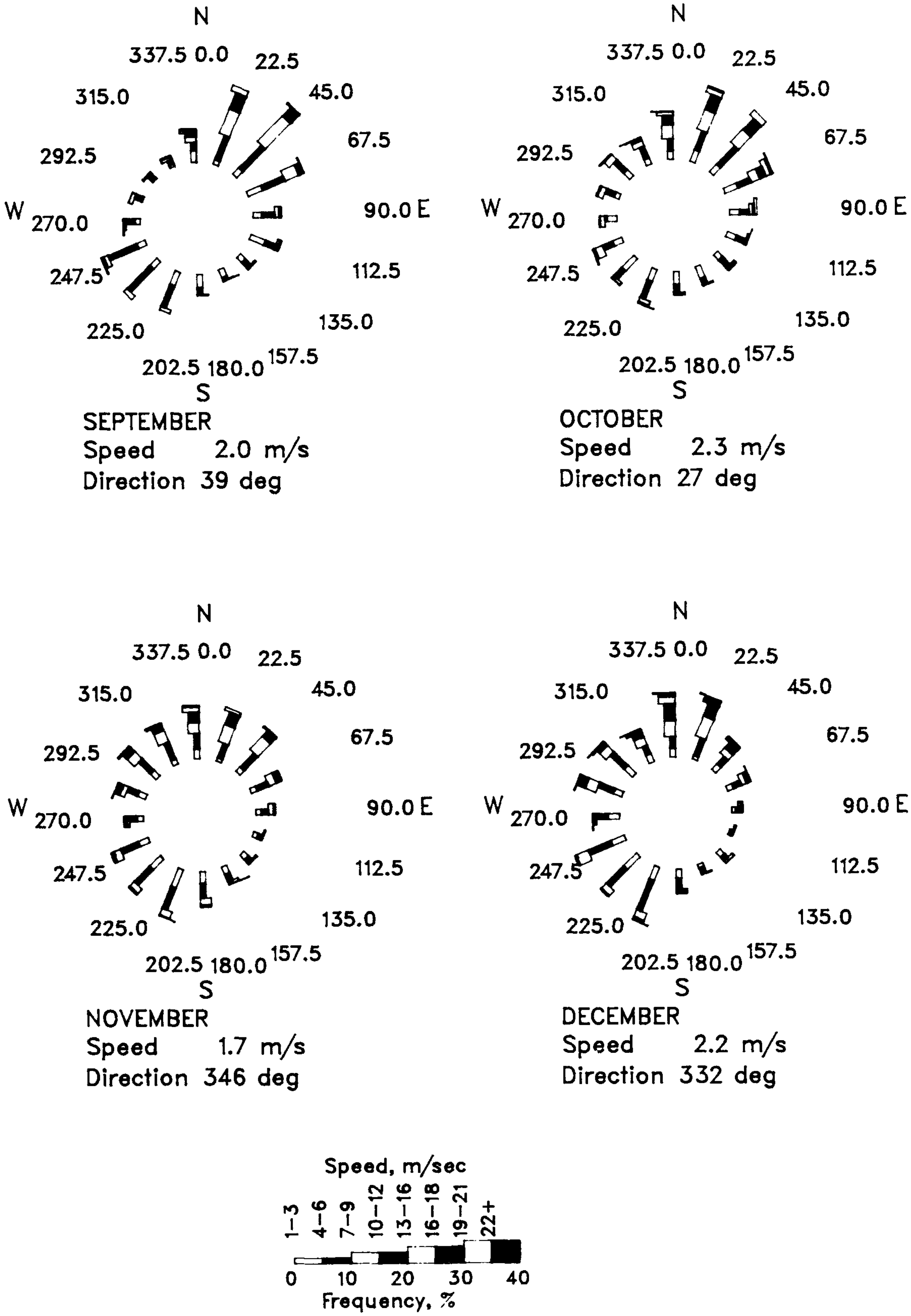


Figure 8. (Sheet 3 of 3)

PART III: WAVES

27. This section presents summaries of the wave data. A discussion of individual major storms is given in Part IX and contains additional wave data for times when wave heights exceeded 2 m at the seaward end of the FRF pier. Appendixes B through E provide more extensive data summaries for each gage, including height and period distributions, wave direction distributions, persistence tables, and spectra during storms.

28. Wave directions (similar to wind directions) at the FRF are seasonally distributed. Waves approach most frequently from north of the pier in the fall and winter and south of the pier in the summer, with the exception of storm waves that approach twice as frequently from north of the pier. Annually, waves are approximately evenly distributed between north and south (resultant wave direction being almost shore-normal).

Measurement Instruments

29. The wave gages included two wave staff (Gages 645 and 625), one buoy (Gage 630), and one pressure (Gage 111) gage as shown in Figure 2 and located as follows:

Gage Type/Number	Distance Offshore from Baseline	Water Depth m	Operational Period
Continuous wire (645)	238 m	3.5	11/84-12/90
Continuous wire (625)	567 m	8	11/78-12/90
Accelerometer buoy (630)	6 km	18	11/78-12/90
Pressure gage (111)	1 km	9	09/86-12/90

Staff gages

30. Two Baylor Company (Houston, TX) parallel cable inductance wave gages (Gage 645 at sta 7+80 and Gage 625 at sta 19+00 (Figure 2)) were mounted on the FRF pier. Rugged and reliable, these gages require little maintenance except to keep tension on the cables and to remove any material that may cause an electrical short between them. They were calibrated prior to installation by creating an electrical short between the two cables at known distances along the cable and recording the voltage output. Electronic signal conditioning amplifiers are used to ensure that the output signals from the gages are within a 0- to 5-V range. Manufacturer-stated gage accuracy is about 1.0 percent, with a 0.1-percent full-scale resolution; full scale is 14 m for Gage 625 and 8.2 m for Gage 645. These gages are susceptible to

lightning damage, but protective measures have been taken to minimize such occurrences. A more complete description of the gages' operational characteristics was given by Grogg (1986).

Buoy gage

31. One Datawell Laboratory for Instrumentation (Haarlem, The Netherlands) Waverider buoy gage (Gage 630) measures the vertical acceleration produced by the passage of a wave. The acceleration signal is double-integrated to produce a displacement signal transmitted by radio to an onshore receiver. The manufacturer stated that wave amplitudes are correct to within 3 percent of their actual value for wave frequencies between 0.065 and 0.500 Hz (corresponding 15- to 2-sec wave periods). The manufacturer also specified that the error gradually increased to 10 percent for wave periods in excess of 20 sec. The results in this report were not corrected for the manufacturer's specified amplitude errors. However, the buoy was calibrated semiannually to ensure that it was within the manufacturer's specification.

Pressure gage

32. One Senso-Metrics, Incorporated (Simi Valley, CA), pressure transduction gage (Gage 111) installed near the ocean bottom measures the pressure changes produced by the passage of waves creating an output signal that is linear and proportional to pressure when operated within its design limits. Predeployment and postdeployment precision calibrations are performed at the FRF using a static deadweight tester. The sensor's range is 0 to 25 psi (equivalent to 0- to 17-m seawater) above atmospheric pressure with a manufacturer-stated accuracy of ±0.25 percent. Copper scouring pads are installed at the sensor's diaphragm to reduce biological fouling, and the system is periodically cleaned by divers.

Digital Data Analysis and Summarization

33. The data were collected, analyzed, and stored on magnetic tape using the FRF's VAX computer. Data sets were normally collected every 6 hr. During storms, the collection was at 3-hr intervals. For each gage, a data set consisted of four contiguous records of 4,096 points recorded at 0.5 Hz (approximately 34-min long), for a total of 2 hr and 16 min. Analysis was performed on individual 34-min records.

34. The analysis program computes the first moment (mean) and the

second moment about the mean (variance) and then edits the data by checking for "jumps," "spikes," and points exceeding the voltage limit of the gage. A jump is defined as a data value greater than five standard deviations from the previous data value, whereas a spike is a data value more than five standard deviations from the mean. If less than five consecutive jumps or spikes are found, the program linearly interpolates between acceptable data and replaces the erroneous data values. The editing stops if the program finds more than five consecutive jumps or spikes or more than a total of 100 bad points or the variance of the voltage is below 1×10^{-5} squared volts. The statistics and diagnostics from the analysis are saved.

35. Sea surface energy spectra are computed from the edited time series. Spectral estimates are computed from smaller data segments obtained by dividing the 4,096-point record into several 512-point segments. The estimates are then ensemble-averaged to produce a more accurate spectrum. These data segments are overlapped by 50 percent (known as the Welch (1967) method) and have been shown to produce improved statistical properties than from nonoverlapped segments. The mean and linear trends are removed from each segment prior to spectral analysis. To reduce sidelobe leakage in the spectral estimates, a data window was applied. The first and last 10 percent of data points was multiplied by a cosine bell (Bingham, Godfrey, and Tukey 1967). Spectra were computed from each segment with a discreet Fast Fourier Transform and then ensemble-averaged. Sea surface spectra from subsurface pressure gages were obtained by applying the linear wave theory transfer function.

36. Unless otherwise stated, wave height in this report refers to the energy-based parameter H_{mo} defined as four times the zeroth moment wave height of the estimated sea surface spectrum (i.e., four times the square root of the variance) computed from the spectrum passband. Energy computations from the spectra are limited to a passband between 0.05 and 0.50 Hz for surface gages and between 0.05 Hz and a high frequency cutoff for subsurface gages. This high frequency limit is imposed to eliminate aliased energy and noise measurements from biasing the computation of H_{mo} and is defined as the frequency where the linear theory transfer function is less than 0.1 (spectral values are multiplied by 100 or more). Smoother and more statistically significant spectral estimates are obtained by band-averaging contiguous spectral components (three components are averaged per band producing a

frequency band width of 0.0117 Hz).

37. Wave period T_p is defined as the period associated with the maximum energy band in the spectrum, which is computed using a 3-point running average band on the spectrum. The peak period is reported as the reciprocal of the center frequency (i.e., $T_p = 1/\text{frequency}$) of the spectral band with the highest energy. A detailed description of the analysis techniques are presented in a report by Andrews (1987).*

Results

38. The wave conditions for the year are shown in Figure 9. For all four gages, the distributions of wave height for the current year and all years combined are presented in Figures 10 and 11, respectively. Distributions of wave period are presented in Figure 12.

39. Multiple year comparisons of data for Gage 111 actually incorporate data for 1985 and 1986 from Gage 640, a discontinued Waverider buoy previously located at the approximate depth and distance offshore as Gage 111 and data for 1987 from Gage 141, located 30 m south of Gage 111.

40. Refraction, bottom friction, and wave breaking contribute to the observed differences in height and period. During the most severe storms when the wave heights exceed 3 m at the seaward end of the pier, the surf zone (wave breaking) has been observed to extend past the end of the pier and occasionally 1 km offshore. This occurrence is a major reason for the differences in the distributions between Gage 630 and the inshore gages. The wave height statistics for the staff gage (Gage 645), located at the landward end of the pier, were considerably lower than those for the other gages. In all but the calmest conditions, this gage is within the breaker zone. Consequently, these statistics represent a lower energy wave climate.

---

* M. E. Andrews. 1987. "Standard Wave Data Analysis Procedures for Coastal Engineering Applications," unpublished report prepared for the US Army Engineer Waterways Experiment Station, Vicksburg, MS.

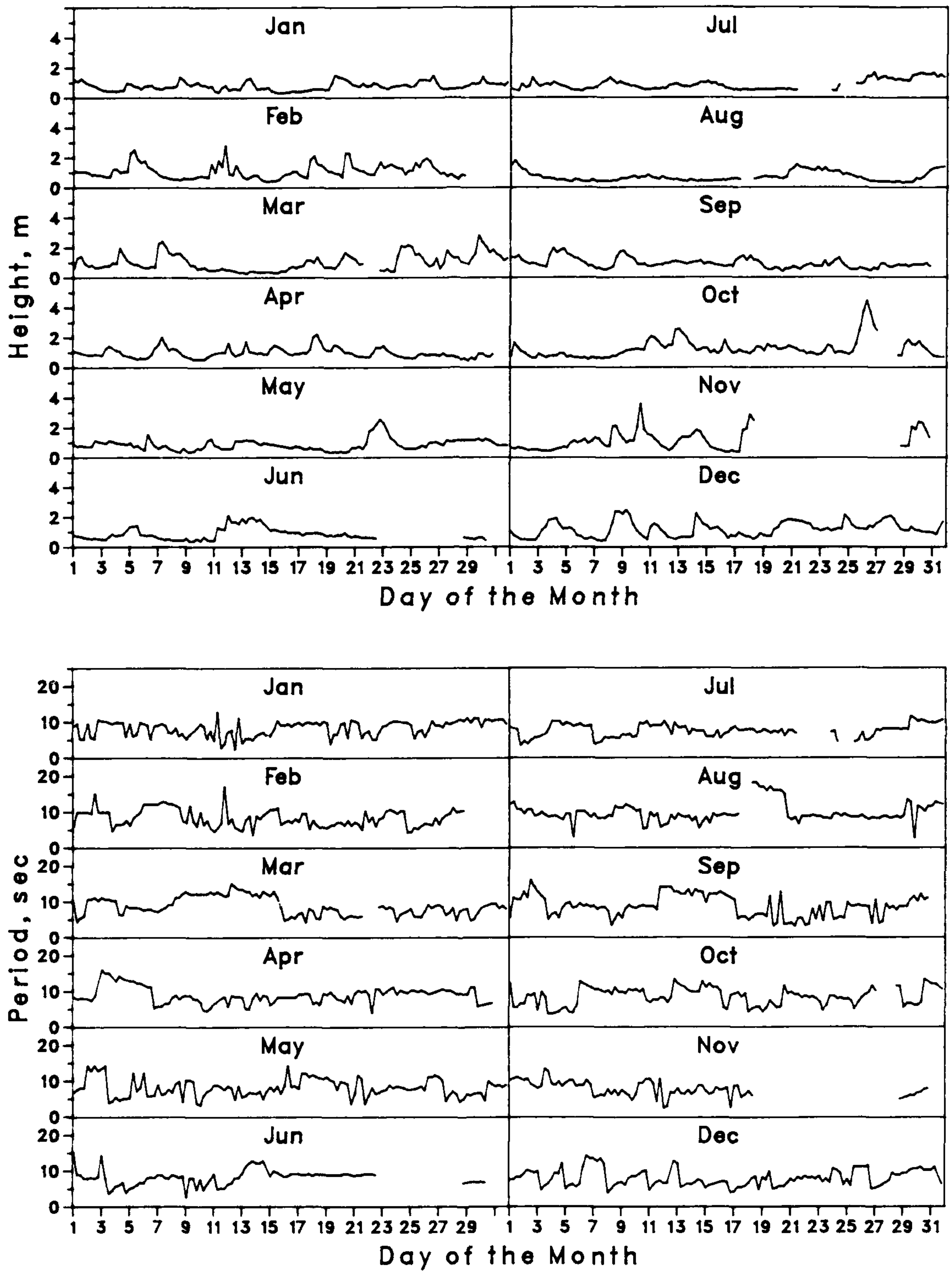


Figure 9. 1990 Time-histories of wave height and period for Gage 630

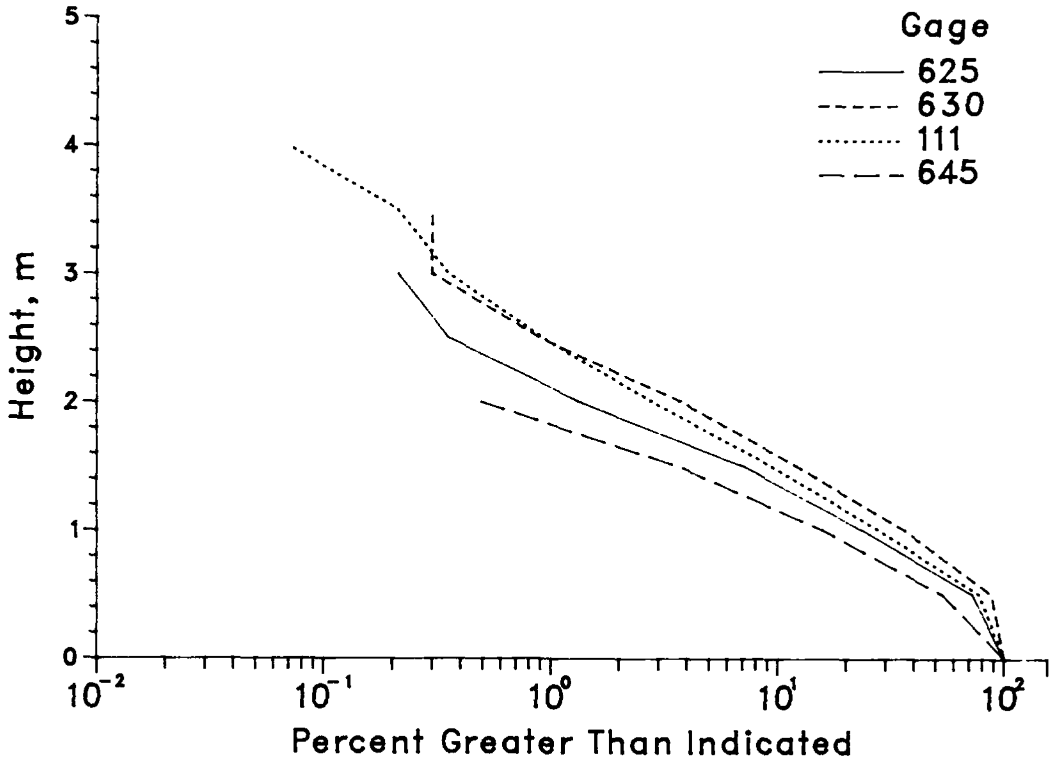


Figure 10. 1990 annual wave height distributions

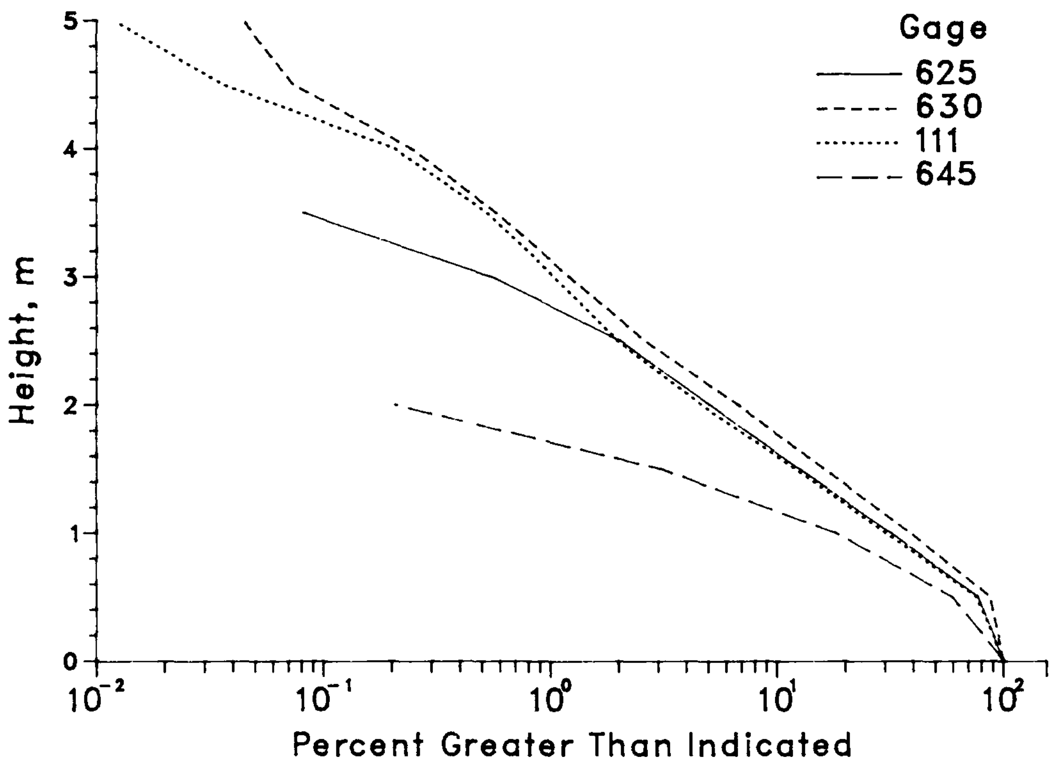


Figure 11. Annual distribution of wave heights for 1980 through 1990

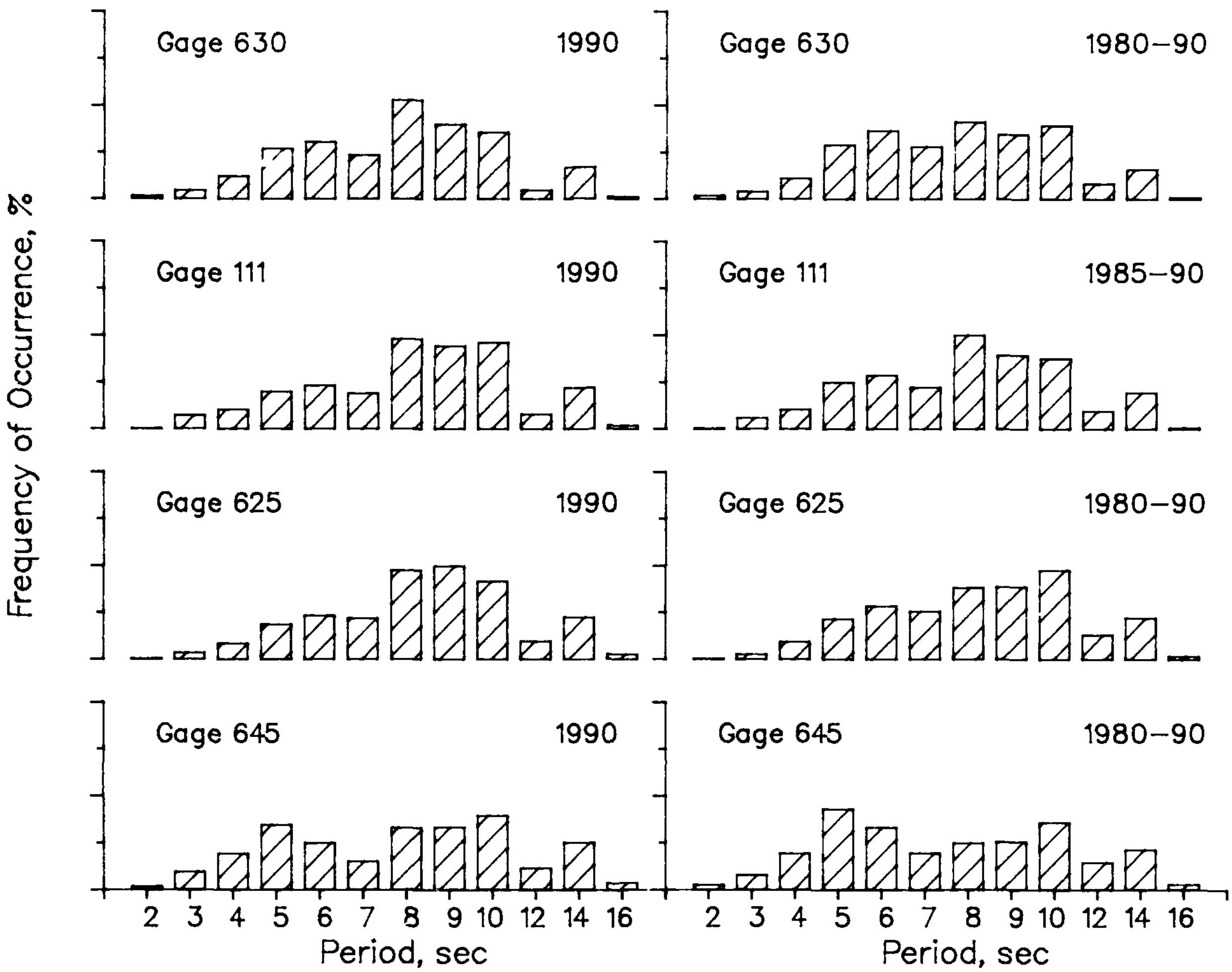


Figure 12. Annual wave period distributions for all gages

41. Summary wave statistics for the current year and all years combined are presented for Gage 630 in Table 3.

Table 3

Wave Statistics for Gage 630

	1990							1980-1990						
	Height				Period			Height				Period		
Month	Mean m	Std. Dev. m	Extreme m	Date	Mean sec	Std. Dev. sec	Number Obs.	Mean m	Std. Dev. m	Extreme m	Date	Mean sec	Std. Dev. sec	Number Obs.
Jan	0.8	0.3	1.5	19	8.3	2.2	123	1.2	0.7	4.5	1983	8.1	2.7	1194
Feb	1.1	0.5	2.8	11	8.3	2.5	111	1.2	0.7	5.1	1987	8.4	2.6	1121
Mar	1.1	0.6	2.8	29	8.8	2.7	119	1.2	0.7	4.7	1983	8.6	2.6	1240
Apr	1.0	0.4	2.2	18	8.9	2.3	115	1.0	0.6	5.0	1988	8.6	2.7	1207
May	0.9	0.4	2.5	22	8.1	2.6	124	0.9	0.5	3.3	1986	8.1	2.4	1229
Jun	0.9	0.5	2.1	12	8.1	2.2	93	0.8	0.4	2.4	1988	7.8	2.2	1138
Jul	0.9	0.4	1.7	26	7.7	1.8	107	0.7	0.3	2.1	1985	8.1	2.5	1164
Aug	0.7	0.4	1.8	1	9.7	2.8	119	0.8	0.5	3.6	1981	8.2	2.5	1180
Sep	1.0	0.4	2.0	4	8.8	3.1	120	1.1	0.6	6.1	1985	8.6	2.7	1191
Oct	1.3	0.7	4.4	26	8.5	2.5	117	1.2	0.7	4.4	1990	8.7	2.8	1239
Nov	1.1	0.7	3.6	10	7.8	2.2	79	1.1	0.7	4.1	1981	7.9	2.7	1037
Dec	1.2	0.6	2.5	9	8.0	2.4	121	1.2	0.8	5.6	1980	8.2	2.9	1067
Annual	1.0	0.5	4.4	Oct	8.5	2.5	1348	1.0	0.6	6.1	Sep 1985	8.3	2.6	14007

42. Annual joint distributions of wave height versus wave period for Gage 630 are presented for 1990 in Table 4, and for all years combined in Table 5. Similar distributions for the other gages are included in Appendixes B-E.

43. Annual distributions of wave directions (relative to True North) based on daily observations of direction at the seaward end of the pier and height from Gage 625 (or Gage 111 when data for Gage 625 were unavailable) are shown in Figure 13. Monthly wave "roses" for 1990 and all years combined are presented in Figures 14 and 15, respectively.

Table 4

Annual (1990) Joint Distribution of H_{mo} versus T_p for Gage 630*

	Period, sec												
Height, m	2.0-2.9	3.0-3.9	4.0-4.9	5.0-5.9	6.0-6.9	7.0-7.9	8.0-8.9	9.0-9.9	10.0-11.9	12.0-13.9	14.0-15.9	16.0-Longer	Total
0.00 - 0.49	15	.	15	15	45	104	378	312	178	52	126	.	1240
0.50 - 0.99	41	163	237	401	497	490	1105	868	838	96	356	37	5133
1.00 - 1.49	.	15	230	445	312	178	482	289	297	37	134	.	2419
1.50 - 1.99	.	.	7	208	185	96	96	104	82	.	52	.	830
2.00 - 2.49	.	.	.	7	163	59	37	.	22	.	.	.	288
2.50 - 2.99	.	.	.	.	15	7	7	.	7	7	7	7	57
3.00 - 3.49	.	.	.	.	.	.	.	.	.	.	.	.	0
3.50 - 3.99	.	.	.	.	.	.	7	15	.	.	.	.	22
4.00 - 4.49	.	.	.	.	.	.	.	7	.	.	.	.	7
4.50 - 4.99	.	.	.	.	.	.	.	.	.	.	.	.	0
5.00 - Greater	.	.	.	.	.	.	.	.	.	.	.	.	0
Total	60	178	489	1076	1217	934	2112	1595	1424	192	675	44	

* Percent occurrence (x100) of height and period.

Table 5

Annual (1980-1990) Joint Distribution of H_{mo} versus T_p for Gage 630 (All Years)*

	Period, sec												
Height, m	2.0-2.9	3.0-3.9	4.0-4.9	5.0-5.9	6.0-6.9	7.0-7.9	8.0-8.9	9.0-9.9	10.0-11.9	12.0-13.9	14.0-15.9	16.0-Longer	Total
0.00 - 0.49	29	14	27	61	89	116	333	281	191	69	126	3	1339
0.50 - 0.99	39	137	253	501	586	522	874	736	787	143	230	17	4825
1.00 - 1.49	.	9	148	403	437	256	263	211	335	41	124	4	2231
1.50 - 1.99	.	.	12	163	246	111	82	79	128	33	76	4	934
2.00 - 2.49	.	.	1	24	93	69	55	38	61	29	39	1	410
2.50 - 2.99	.	.	.	1	9	31	17	14	34	10	24	1	141
3.00 - 3.49	.	.	.	.	1	11	13	12	15	4	8	.	64
3.50 - 3.99	.	.	.	.	.	1	6	7	11	4	4	.	33
4.00 - 4.49	.	.	.	.	.	.	1	4	7	1	4	.	17
4.50 - 4.99	.	.	.	.	.	.	.	1	2	.	.	.	3
5.00 - Greater	.	.	.	.	.	.	1	.	1	1	1	.	4
Total	68	160	441	1153	1461	1117	1645	1383	1572	335	636	30	

* Percent occurrence (x100) of height and period.

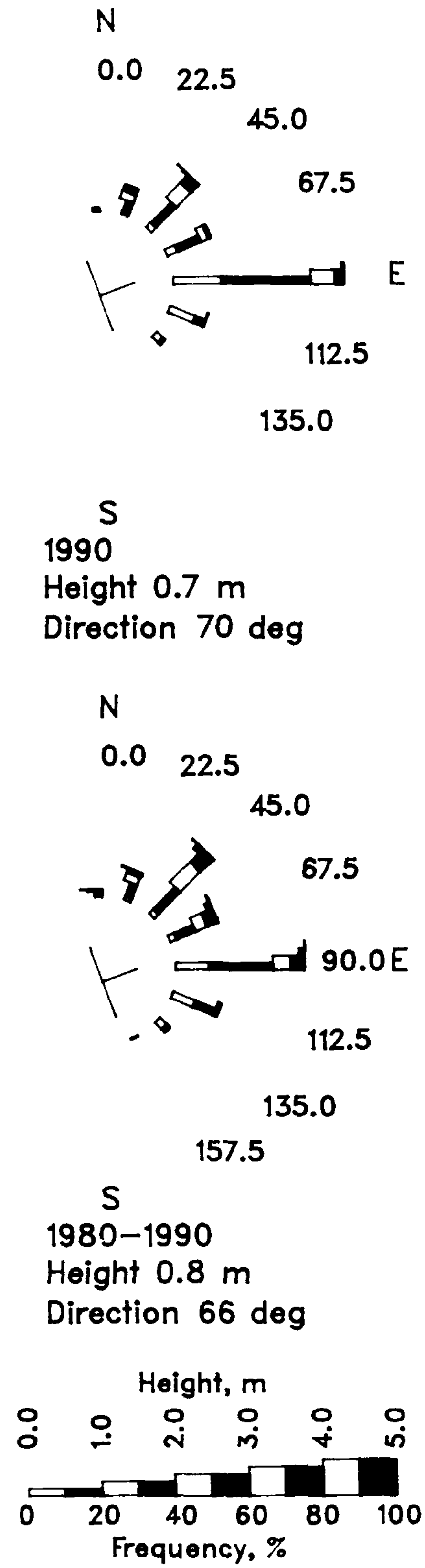


Figure 13. Annual wave roses

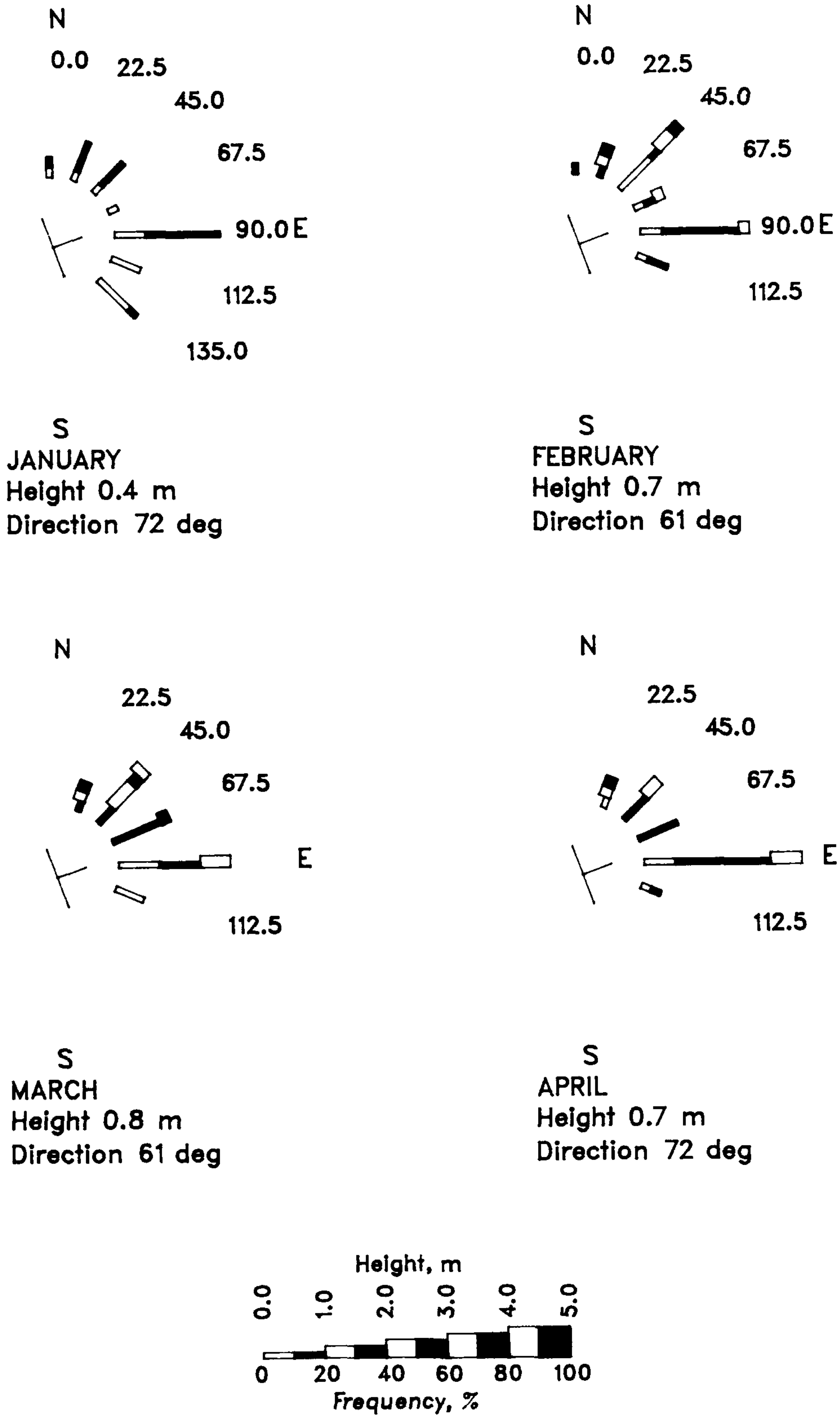


Figure 14. Monthly wave roses for 1990 (Sheet 1 of 3)

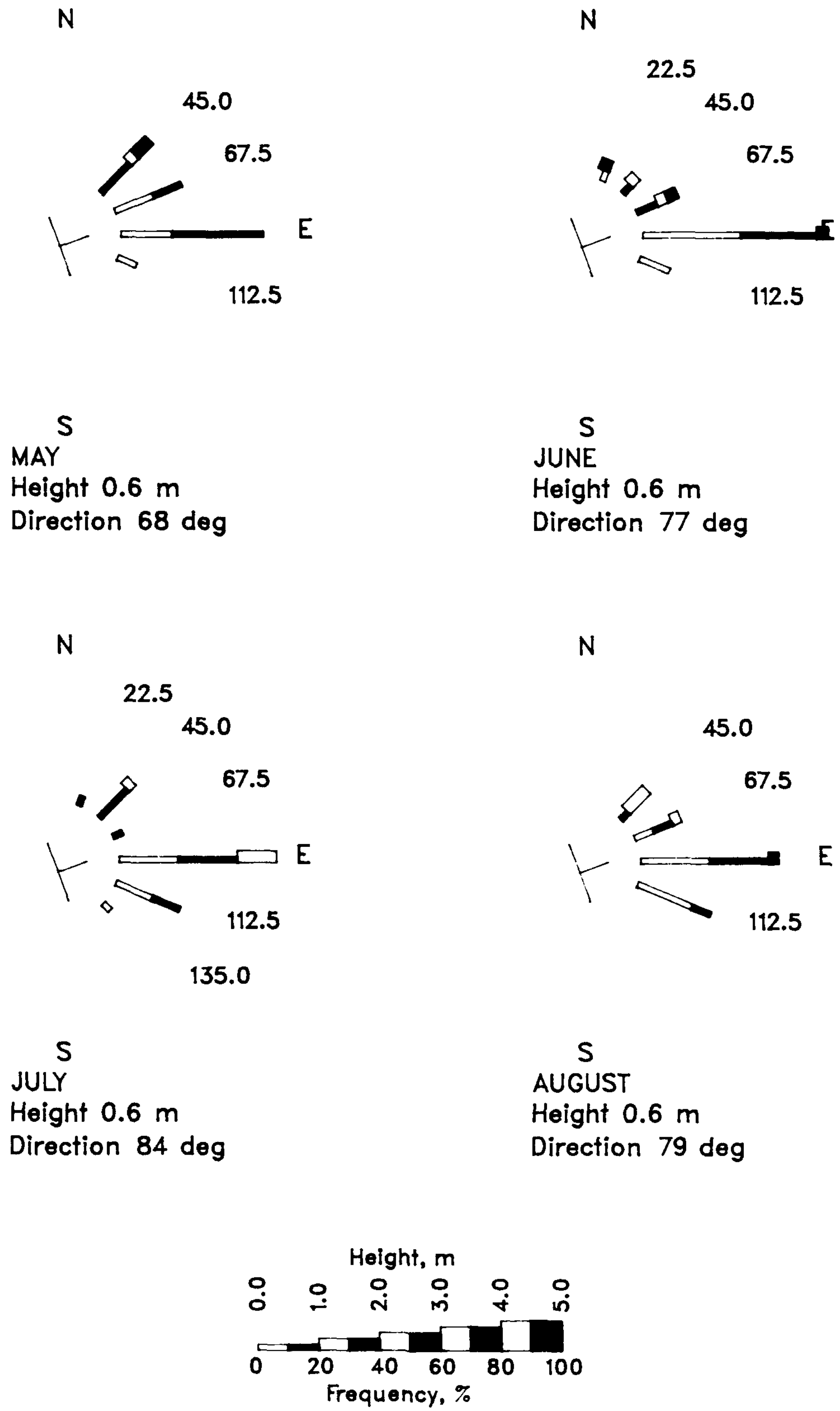


Figure 14. (Sheet 2 of 3)

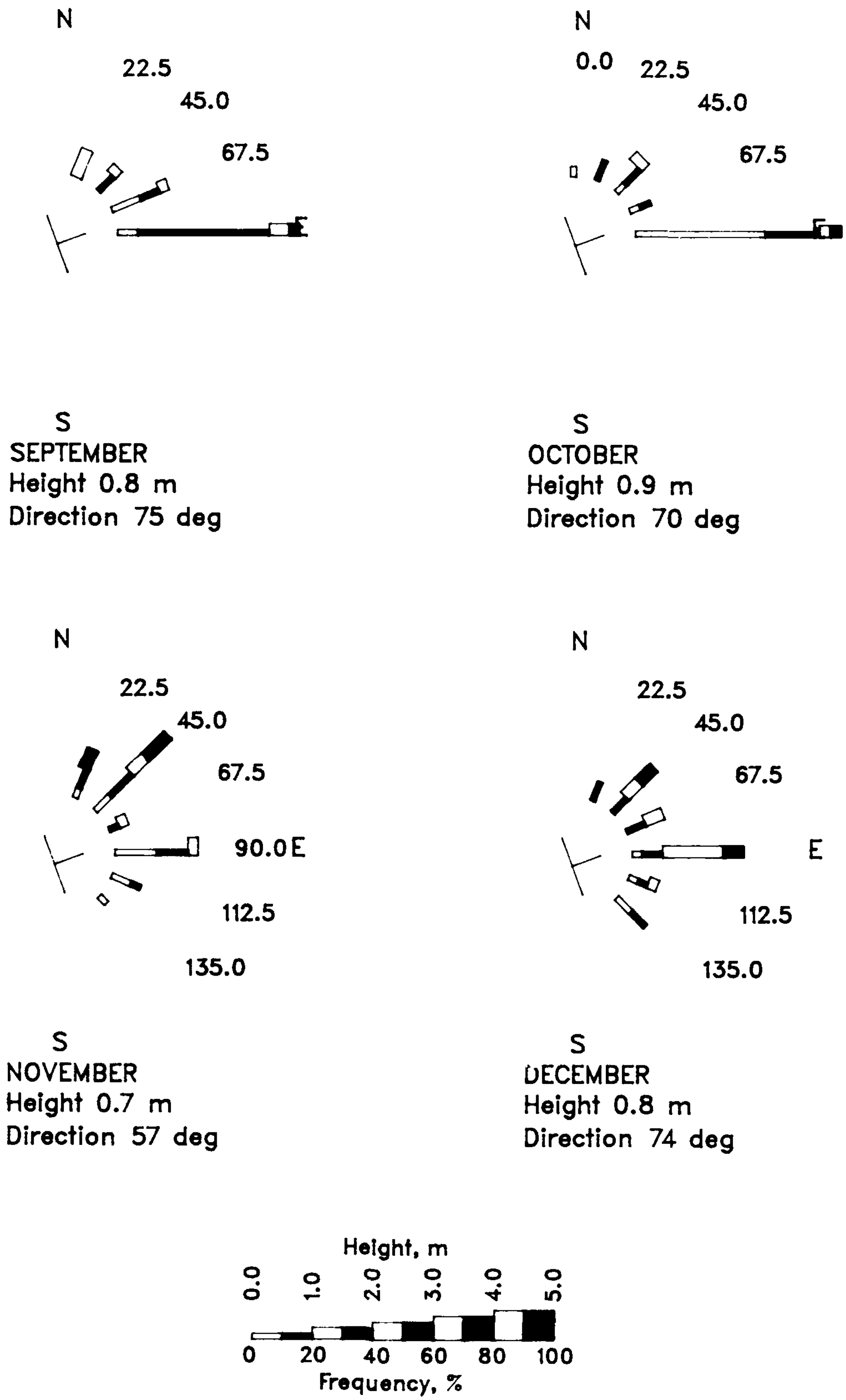


Figure 14. (Sheet 3 of 3)

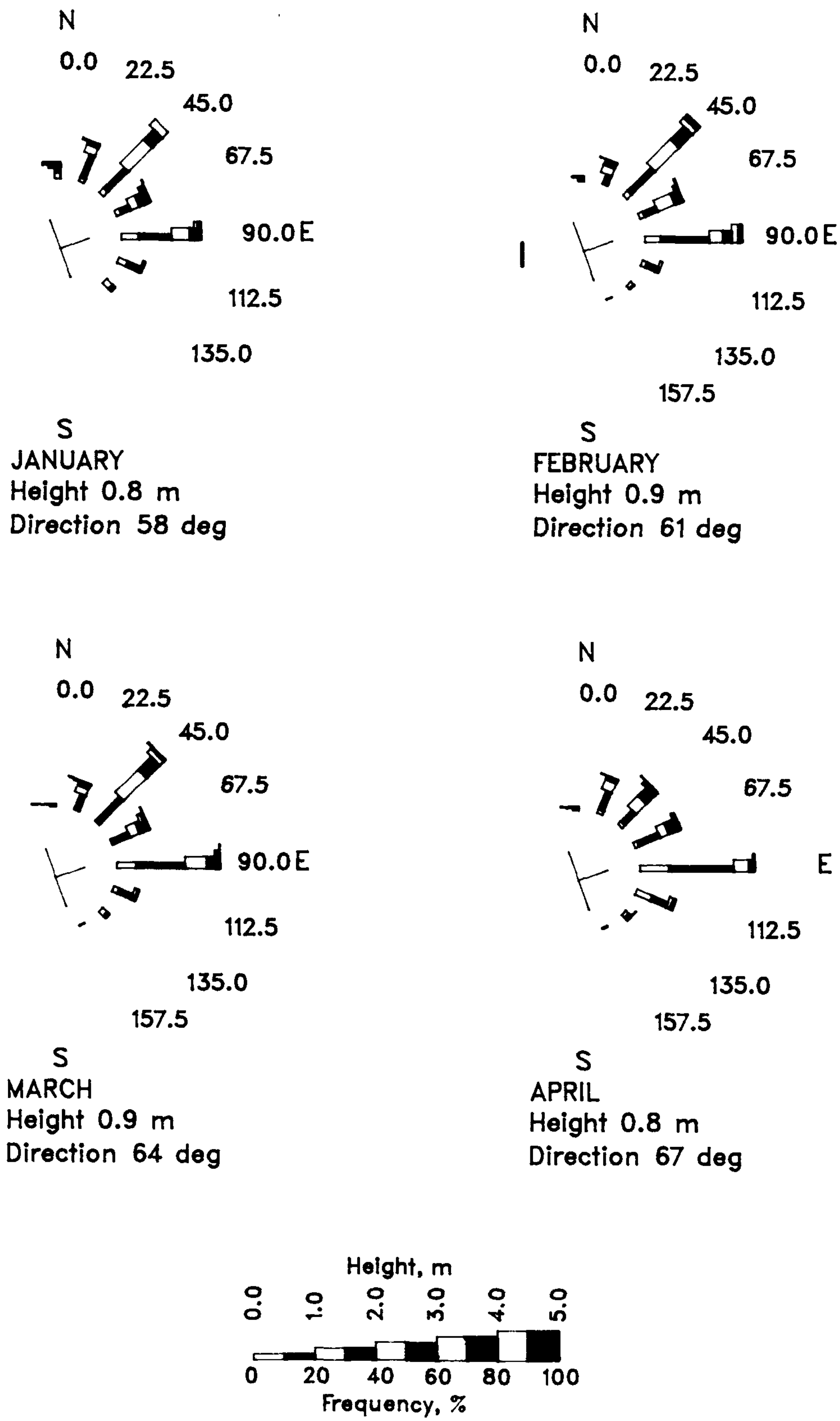


Figure 15. Monthly wave roses for 1980 through 1990
(Sheet 1 of 3)

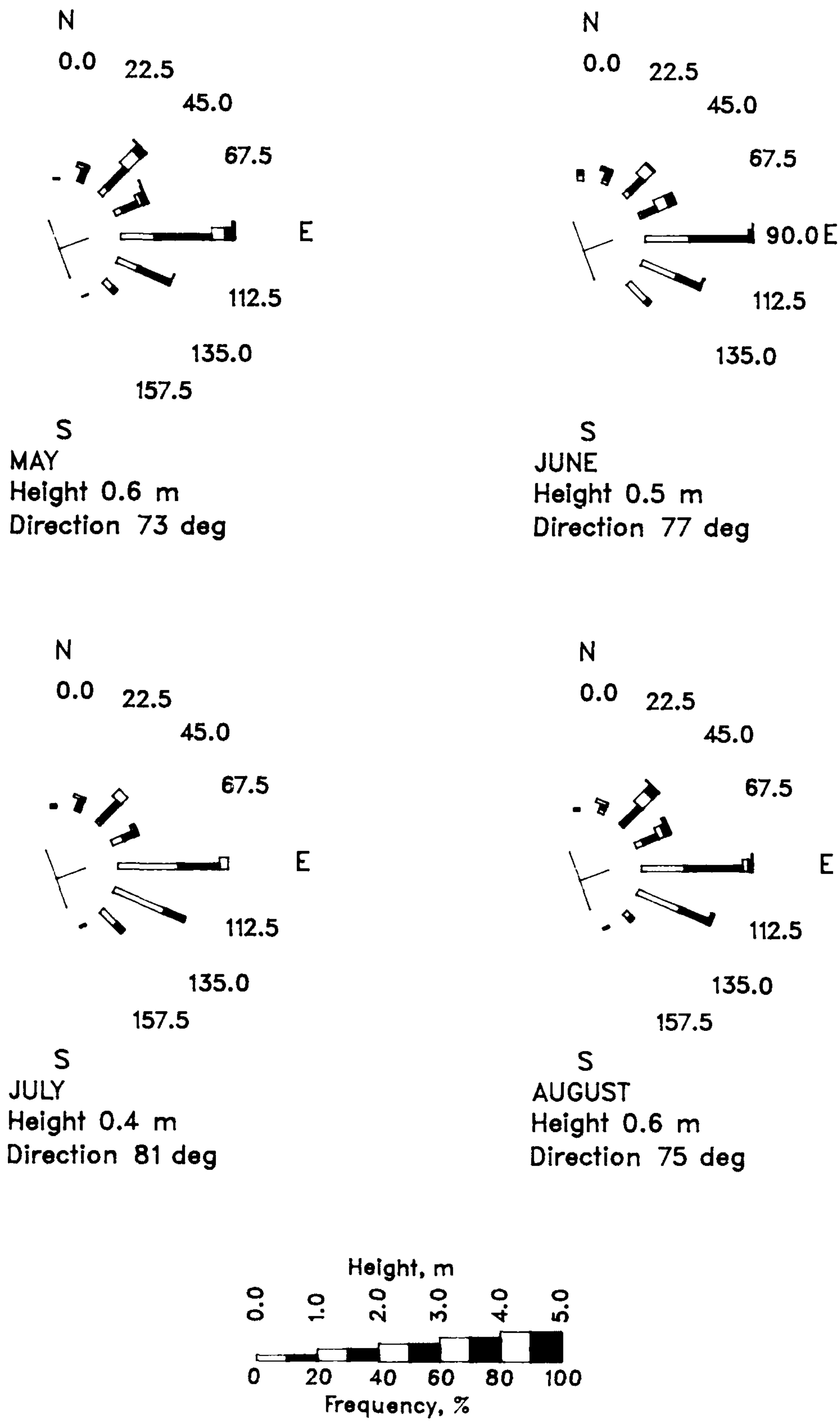


Figure 15. (Sheet 2 of 3)

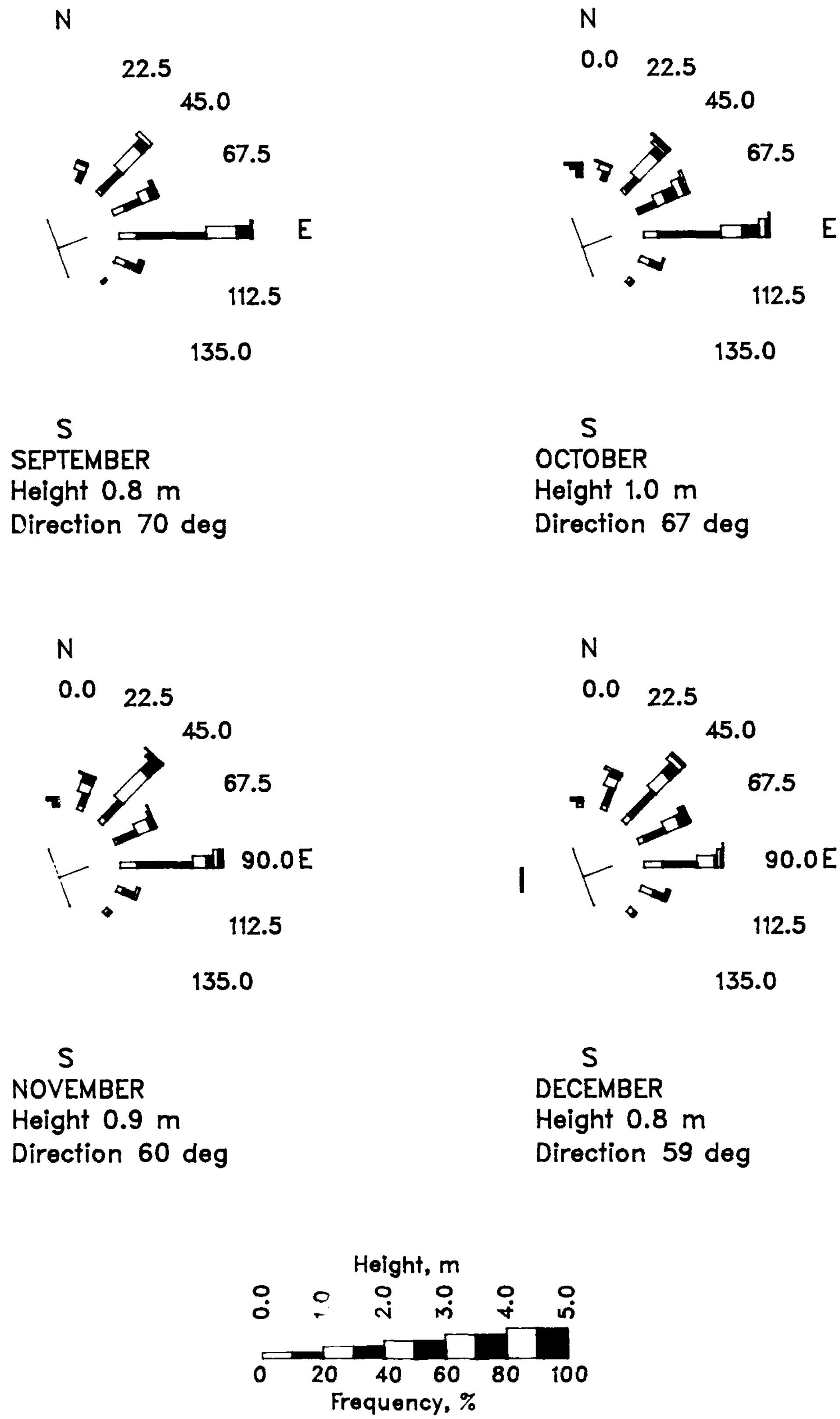


Figure 15 (Sheet 3 of 3)

PART IV: CURRENTS

44. Surface current speed and direction at the FRF are influenced by winds, waves, and, indirectly, by the bottom topography. The extent of the respective influence varies daily. However, winds tend to dominate the currents at the seaward end of the pier, whereas waves dominate within the surf zone.

Observations

45. Near 0700 EST, daily observations of surface current speed and direction were made at (a) the seaward end of the pier, (b) the midsurf position on the pier, and (c) 10 to 15 m from the beach 500 m updrift of the pier. Surface currents were determined by observing the movement of dye on the water surface.

Results

46. Annual mean and mean currents for 1980 through 1990 are presented in Table 6 and in Figure 16. Figure 16 shows the daily and average annual measurements at the beach, pier midsurf, and pier end locations. Since the relative influences of the winds and waves vary with position from shore, the current speeds and, to some extent, direction vary at the beach, midsurf, and pier end locations. Magnitudes generally are largest at the midsurf location and lowest at the end of the pier.

Table 6

Mean Longshore Surface Currents*

Month	Pier End, cm/sec 1990	Pier End, cm/sec 1980-1990	Pier Midsurf, cm/sec 1990	Pier Midsurf, cm/sec 1980-1990	Beach, cm/sec 1990	Beach, cm/sec 1980-1990
Jan	5	15	-11	16	-13	10
Feb	11	17	-6	10	6	12
Mar	13	16	-1	12	6	12
Apr	15	11	-12	0	2	7
May	8	10	-5	-4	-3	-2
Jun	0	5	-19	-9	-15	-7
Jul	11	4	-31	-17	-19	-11
Aug	17	9	-10	-11	-4	-5
Sep	11	7	-10	-7	2	-3
Oct	-5	8	-22	-1	-31	1
Nov	18	13	28	8	15	11
Dec	9	14	15	17	10	11
Annual	10	11	-6	1	-4	3

* + = southward; - = northward.

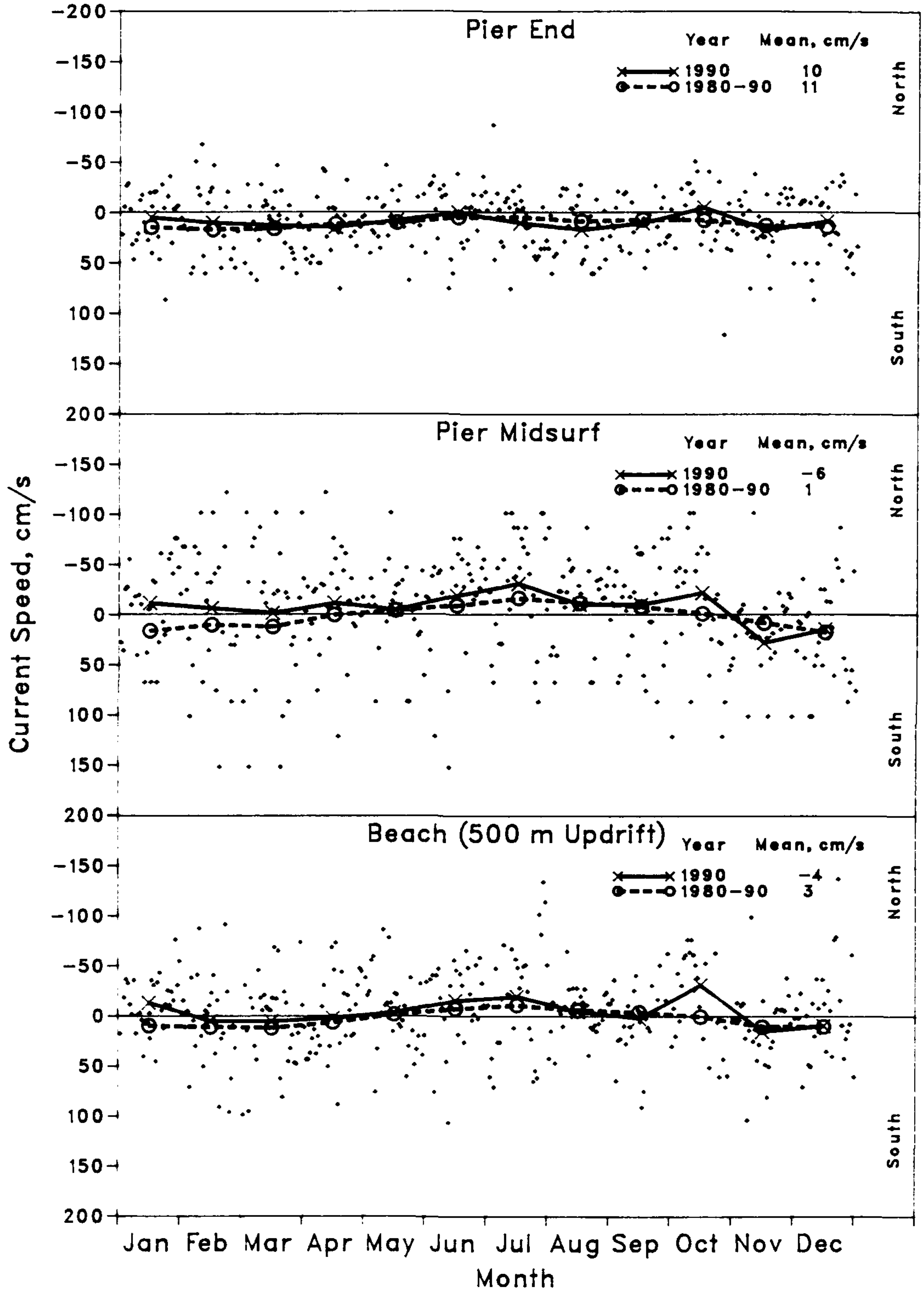


Figure 16. Daily current speeds and directions with monthly means for 1990

PART V: TIDES AND WATER LEVELS

Measurement Instrument

47. Water level data were obtained from a NOAA/NOS control tide station (sta 865-1370) located at the seaward end of the research pier (Figure 2) by using a Leupold and Stevens, Inc. (Beaverton, OR), digital tide gage. This analog-to-digital recorder is a float-activated, negator-spring, counterpoised instrument that mechanically converts the vertical motion of a float into a coded, punched paper tape record. The below-deck installation at pier sta 19+60 consisted of a 30.5-cm-diam stilling well with a 2.5-cm orifice and a 21.6-cm-diam float.

48. Operation and tending of the tide gage conformed to NOS standards. The gage was checked daily for proper operation of the punch mechanism and for accuracy of the time and water level information. The accuracy was determined by comparing the gage level reading with a level read from a reference electric tape gage. Once a week, a heavy metal rod was lowered down the stilling well and through the orifice to ensure free flow of water into the well. During the summer months, when biological growth was most severe, divers inspected and cleaned the orifice opening as required.

49. The tide station was inspected quarterly by a NOAA/NOS tide field group. Tide gage elevation was checked using existing NOS control positions, and the equipment was checked and adjusted as needed. Both NOS and FRF personnel also reviewed procedures for tending the gage and handling the data. Any specific comments on the previous months of data were discussed to ensure data accuracy.

50. Digital paper tape records of tide heights taken every 6 min were analyzed by the Tides Analysis Branch of NOS. An interpreter created a digital magnetic computer tape from the punch paper tape, which was then processed on a large computer. First, a listing of the instantaneous tidal height values was created for visual inspection. If errors were encountered, a computer program was used to fill in or recreate bad or missing data using correct values from the nearest NOS tide station and accounting for known time lags and elevation anomalies. The data were plotted, and a new listing was generated and rechecked. When the validity of the data had been confirmed, monthly tabulations of daily highs and lows, hourly heights (instantaneous

height selected on the hour), and various extreme and/or mean water level statistics were computed.

Results

51. Tides at the FRF are semidiurnal with both daily high and low tides approximately equal. Tide height statistics are presented in Table 7. Figure 17 plots the monthly tide statistics for all available data, and Figure 18 compares the distribution of daily high and low water levels and hourly tide heights. The monthly or annual mean sea level (MSL) reported is the average of the hourly heights, whereas the mean tide level is midway between mean high water (MHW) and mean low water (MLW), which are the averages of the daily high- and low-water levels, respectively, relative to NGVD. Mean range (MR) is the difference between MHW and MLW levels, and the lowest water level for the month is the extreme low (EL) water, while the highest water level is the extreme high (EH) water level.

Table 7

Tide Height Statistics*

Month or Year	Mean High Water	Mean Tide Level	Mean Sea Level	Mean Low Water	Mean Range	Extreme High	Date	Extreme Low	Date
					1990				
Jan	36	-4	-4	-46	82	76	9	-75	28
Feb	41	0	1	-41	82	94	5	-78	25
Mar	43	2	2	-40	83	81	29	-64	28
Apr	43	3	3	-38	81	82	26	-66	11
May	52	11	11	-29	81	109	22	-47	11
Jun	49	9	9	-32	81	86	22	-53	3
Jul	49	10	10	-30	79	74	22	-54	21
Aug	56	17	17	-22	78	92	21	-46	20
Sep	59	20	20	-20	79	87	4	-44	20
Oct	57	16	16	-25	82	99	26	-65	5
Nov	54	13	13	-28	82	94	18	-53	28
Dec	47	5	6	-36	83	89	3	-74	31
1990	49	9	9	-32	81	109	May	-78	Feb
					Prior Years				
1989	49	9	9	-31	80	199	Mar	-77	Apr
1988	46	6	7	-33	79	129	Apr	-72	Dec
1987	55	15	16	-24	79	113	Jan	-63	Nov
1986	60	13	13	-35	95	123	Dec	-108	Jan
1985	59	10	11	-37	96	136	Dec	-93	Apr
1984	64	16	16	-32	97	147	Oct	-77	Jul
1983	68	19	19	-30	98	143	Jan	-73	Mar
1982	58	8	9	-42	99	127	Oct	-108	Feb
1981	59	8	9	-42	101	149	Nov	-110	Apr
1980	59	8	8	-43	102	118	Mar	-119	Mar
1979	60	9	9	-43	103	121	Feb	-95	Sep
1979-1990	57	11	11	-35	93	199	Mar 1989	-119	Mar 1980

* Measurements are in centimeters.

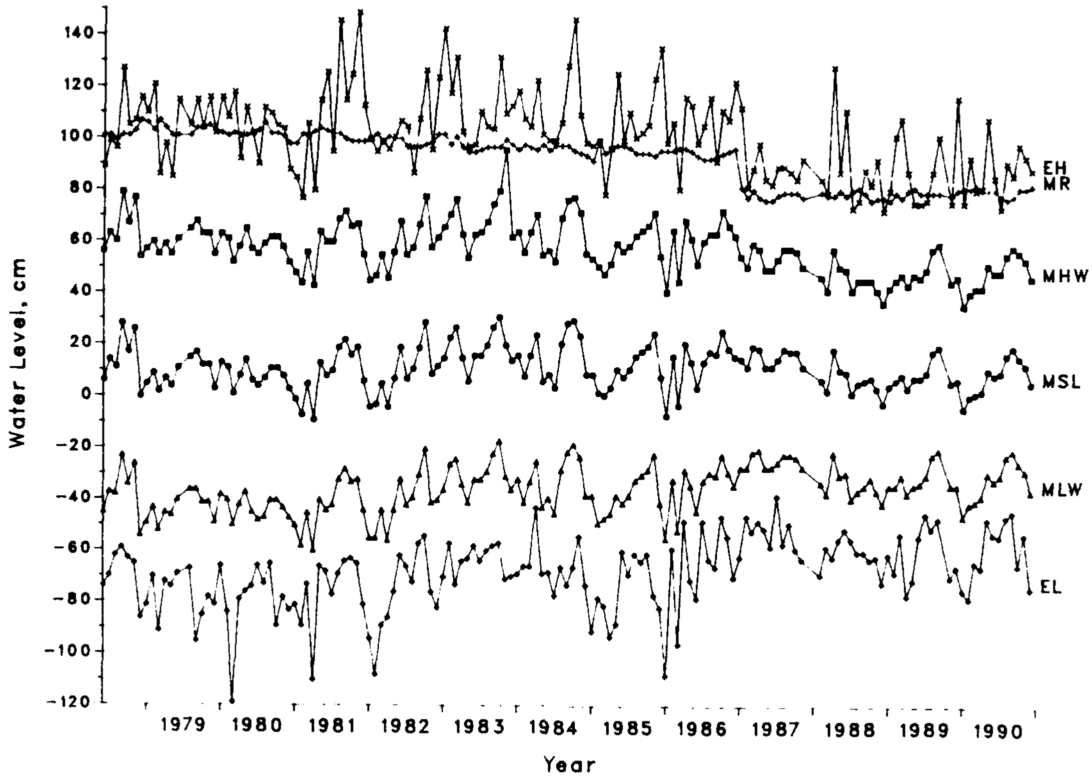


Figure 17. Monthly tide and water level statistics relative to NGVD

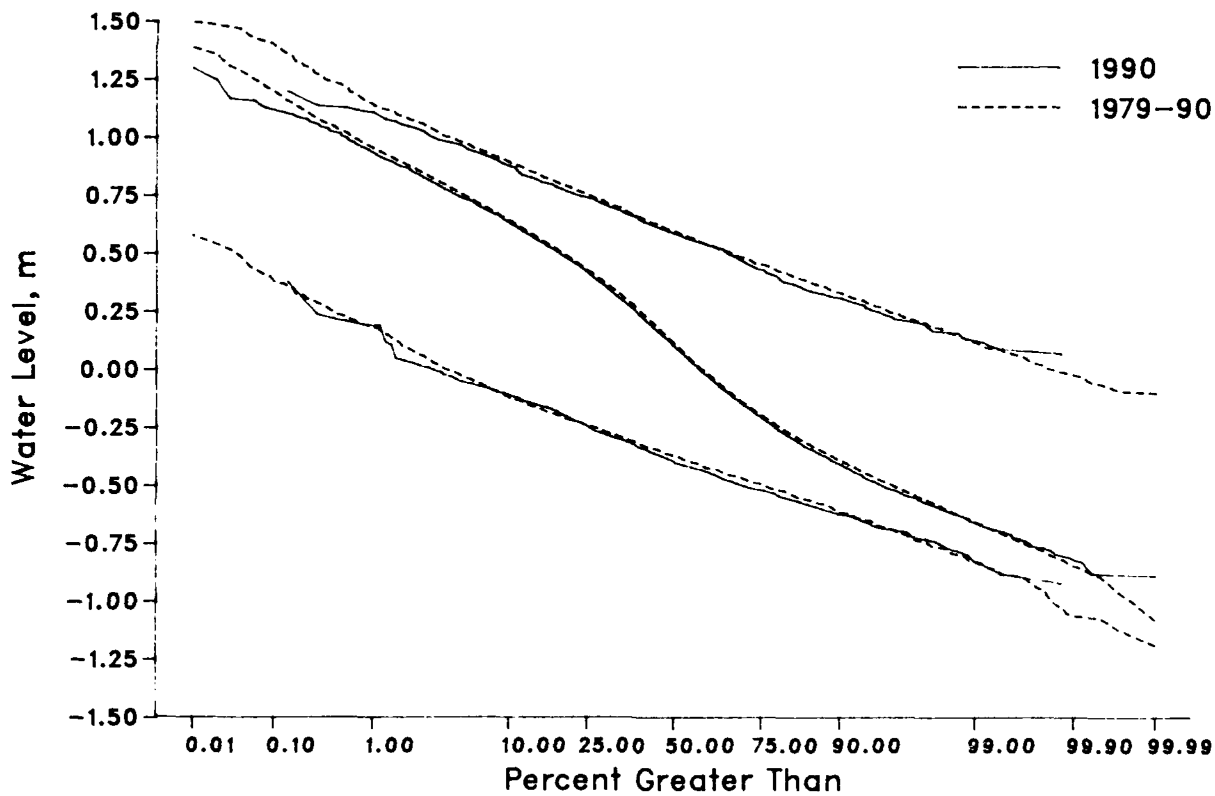


Figure 18. Distributions of hourly tide heights and high- and low-water levels

PART VI: WATER CHARACTERISTICS

52. Monthly averages of daily measurements of surface water temperature, visibility, and density at the seaward end of the FRF pier are given in Table 8. The summaries represent single observations made near 0700 EST and, therefore, may not reflect daily average conditions since such characteristics can change within a 24-hr period. Large temperature variations were common when there were large differences between the air and water temperatures and variations in wind direction. From past experience, persistent onshore winds move warmer surface water toward the shoreline, although offshore winds cause colder bottom water to circulate shoreward resulting in lower temperatures.

Table 8

Mean Surface Water Characteristics

	Temperature deg C		Visibility m		Density g/cm^3	
Month	1990	1980-1990	1990	1980-1990	1990	1980-1990
Jan	6.7	5.9	2.0	1.3	1.0241	1.0236
Feb	9.0	5.3	2.5	1.8	1.0236	1.0232
Mar	10.1	6.9	2.1	1.6	1.0232	1.0229
Apr	12.6	11.0	2.5	2.0	1.0223	1.0226
May	15.4	15.3	3.1	2.4	1.0230	1.0222
Jun	20.2	19.3	4.0	3.5	1.0212	1.0215
Jul	22.5	22.0	4.3	3.8	1.0216	1.0215
Aug	26.4	23.7	4.0	3.2	1.0195	1.0204
Sep	25.1	23.0	2.6	2.2	1.0199	1.0209
Oct	21.8	19.5	2.1	1.5	1.0221	1.0217
Nov	15.7	14.9	2.0	1.0	1.0224	1.0229
Dec	11.9	10.0	1.5	1.1	1.0234	1.0235
Annual	16.4	14.7	2.7	2.1	1.0221	1.0222

Temperature

53. Daily sea surface water temperatures (Figure 19) were measured with an NOS water sampler and thermometer. Monthly mean water temperatures (Table 8) varied with the air temperatures (see Table 2).

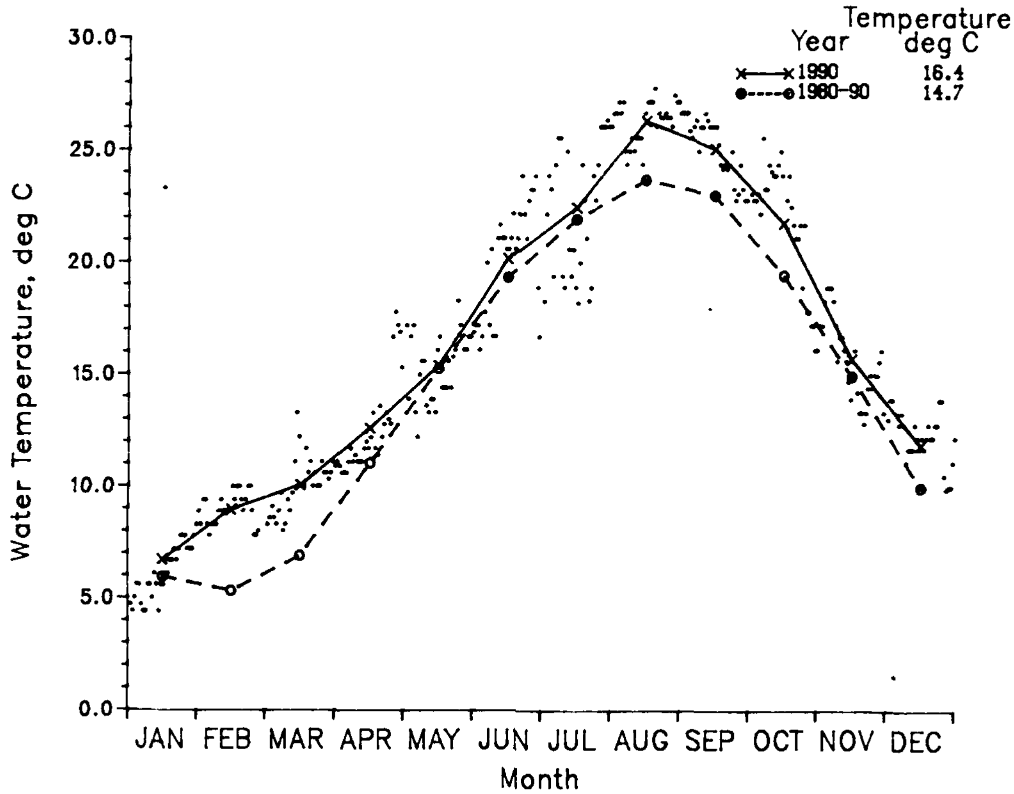


Figure 19. Daily water temperature values with monthly means

Visibility

54. Visibility in coastal nearshore waters depends on the amount of salts, soluble organic material, detritus, living organisms, and inorganic particles in the water. These dissolved and suspended materials change the absorption and attenuation characteristics of the water that vary daily and yearly.

55. Visibility was measured with a 0.3-m-diam Secchi disk, and similar to water temperature, variation was related to onshore and offshore winds. Onshore winds moved warm clear surface water toward shore, whereas offshore winds brought up colder bottom water with large concentrations of suspended matter. Figure 20 presents the daily and monthly mean surface visibility values for the year. Large variations were common, and visibility less than 1 m was expected in any month. Monthly means are given in Table 8.

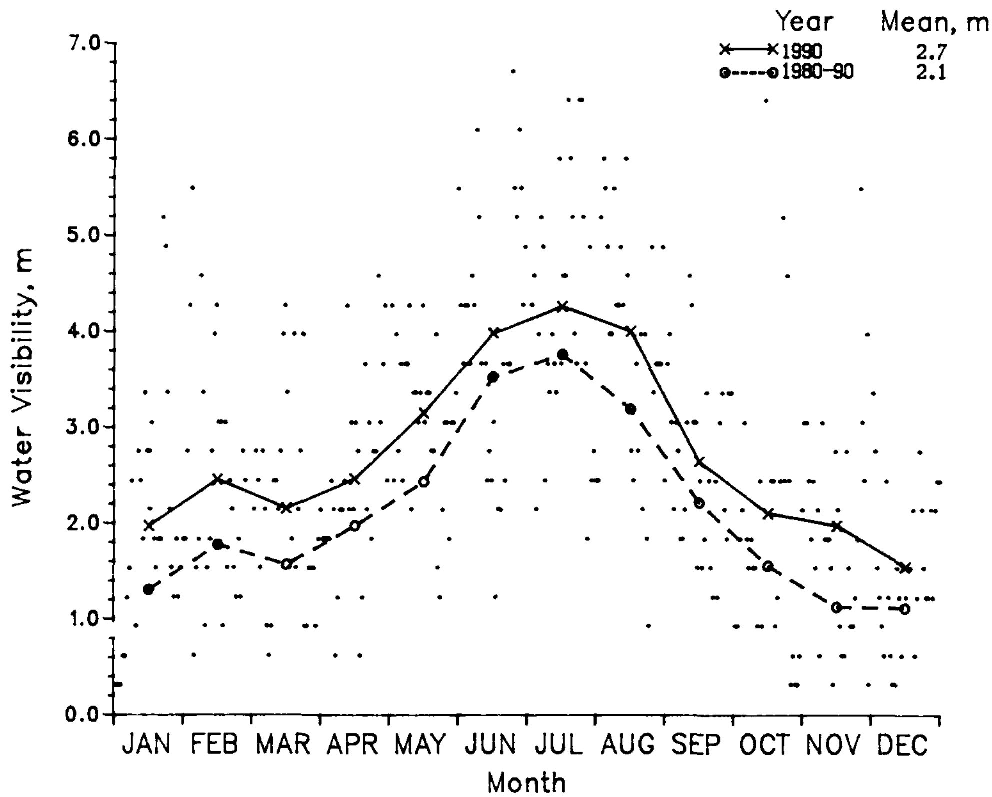


Figure 20. Daily water visibility values with monthly means

Density

56. Daily and monthly mean surface density values, plotted in Figure 21, were measured with a hydrometer. Monthly means are also given in Table 8.

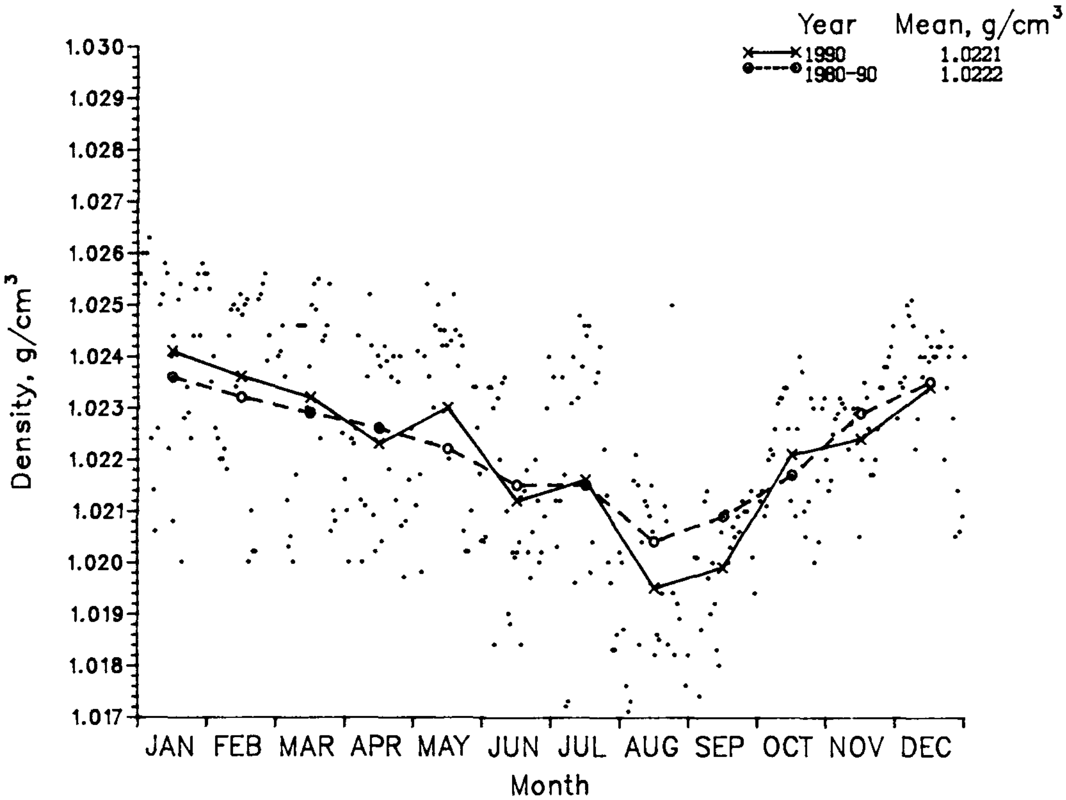


Figure 21. Daily water density values with monthly means

PART VII: SURVEYS

57. Waves and currents interacting with bottom sediments produce changes in the beach and nearshore bathymetry. These changes can occur very rapidly in response to storms or slowly as a result of persistent but less forceful seasonal variations in wave and current conditions.

58. Nearshore bathymetry at the FRF is characterized by regular shore-parallel contours, a moderate slope, and a barred surf zone (usually an outer storm bar in water depths of about 4.5 m and an inner bar in water depths between 1.0 and 2.0 m). This pattern is interrupted in the immediate vicinity of the pier where a permanent trough runs under much of the pier, ending in a scour hole where depths can be up to 3.0 m greater than the adjacent bottom (Figure 22). This trough, which apparently is the result of the interaction of waves and currents with the pilings, varies in shape and depth with changing wave and current conditions. The effect of the pier on shore-parallel contours occurs as far as 300 m away, and the shoreline may be affected up to 350 m from the pier (Miller, Birkemeier, and DeWall 1983).

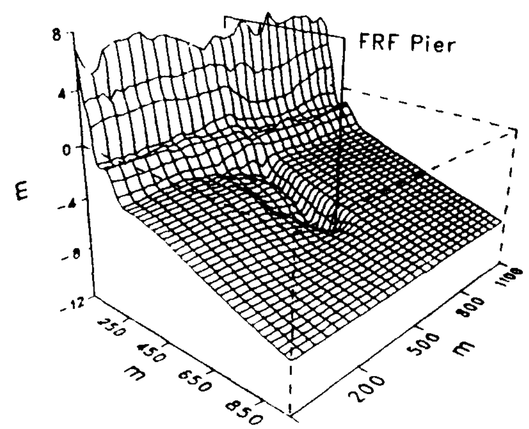


Figure 22. Permanent trough under the FRF pier, 6 September 1990

59. To document the temporal and spatial variability in bathymetry, surveys were conducted approximately monthly of an area extending 600 m north and south of the pier and approximately 950 m offshore. Contour maps resulting from these surveys along with plots of change in elevation between surveys are given in Appendix A.

60. All surveys used the Coastal Research Amphibious Buggy (CRAB), a 10.7-m-tall amphibious tripod, and a Zeiss electronic surveying system described by Birkemeier and Mason (1984). The profile locations are shown in each figure in Appendix A. Survey accuracy was about ±3 cm horizontally and vertically. Monthly soundings along both sides of the FRF pier were collected by lowering a weighted measuring tape to the bottom and recording the distance below the pier deck. Soundings were taken midway between the pier pilings to minimize errors caused by scour near the pilings.

61. A history of bottom elevations below Gages 645 and 625 is presented in Figure 23 for their respective pier stations of sta 7+80 (238 m) and sta 18+60 (567 m) along with intermediate locations, 323 and 433 m.

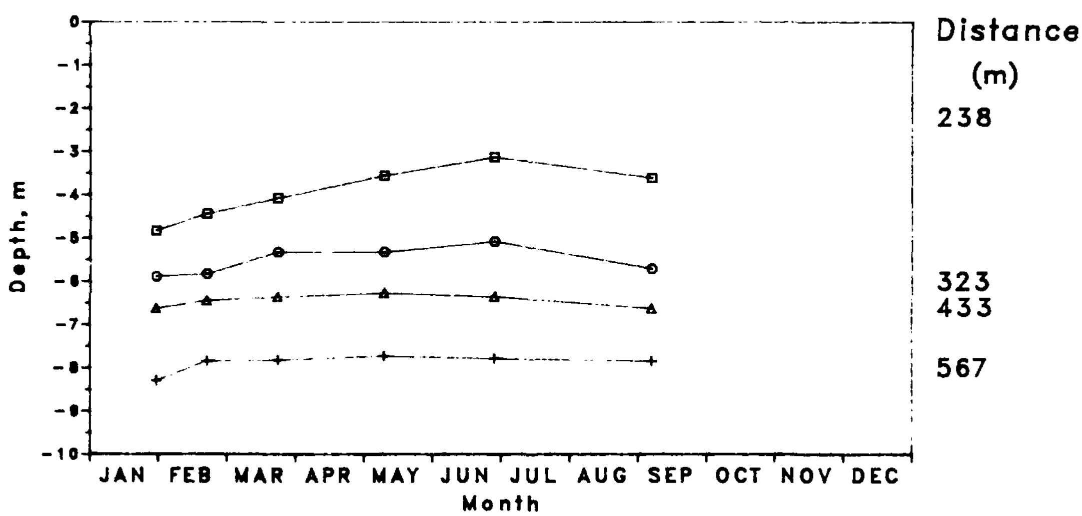


Figure 23. Time-history of bottom elevations at selected locations under the FRF pier

PART VIII: PHOTOGRAPHY

Aerial Photographs

62. Aerial photography was taken quarterly using a 23-cm aerial mapping camera at a scale of 1:12,000. All coverage was at least 60-percent overlap, with flights flown as closely as possible to low tide between 1000 and 1400 EST with less than 10-percent cloud cover. The flight lines covered are shown in Figure 24. Figure 25 is a sample of the imagery obtained on 17 April 1990; the available aerial photographs for the year are:

Date	Flight Lines	Format
14 Jan	1	B/W
23 Jan	2	Color
	3	B/W

Beach Photographs

63. Daily color slides of the beach were taken using a 35-mm camera from the same location on the pier looking north and south (Figure 26). The location from which each picture was taken, as well as the date, time, and a brief description of the picture, was marked on the slides.

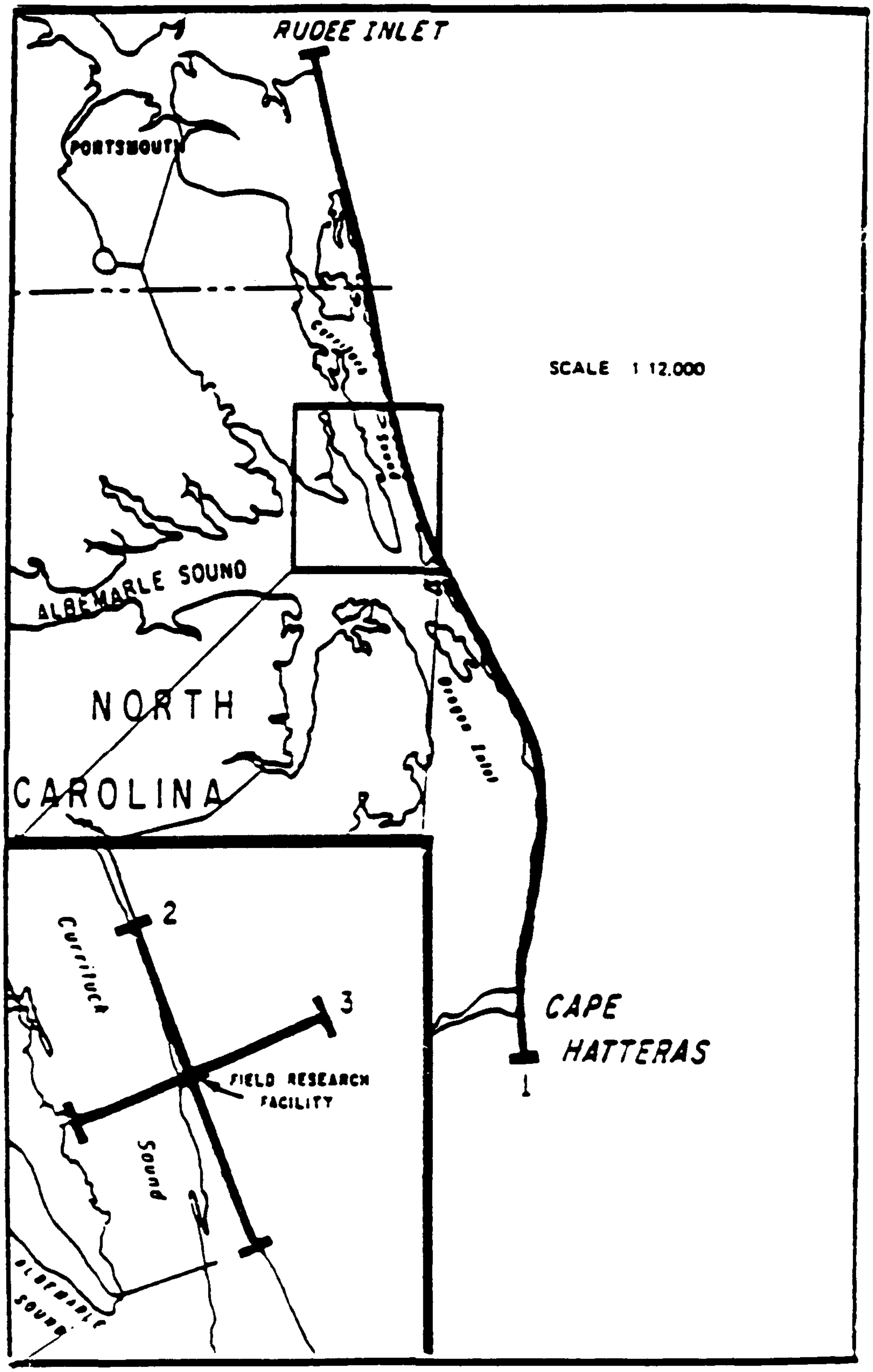


Figure 24. Aerial photography flight lines

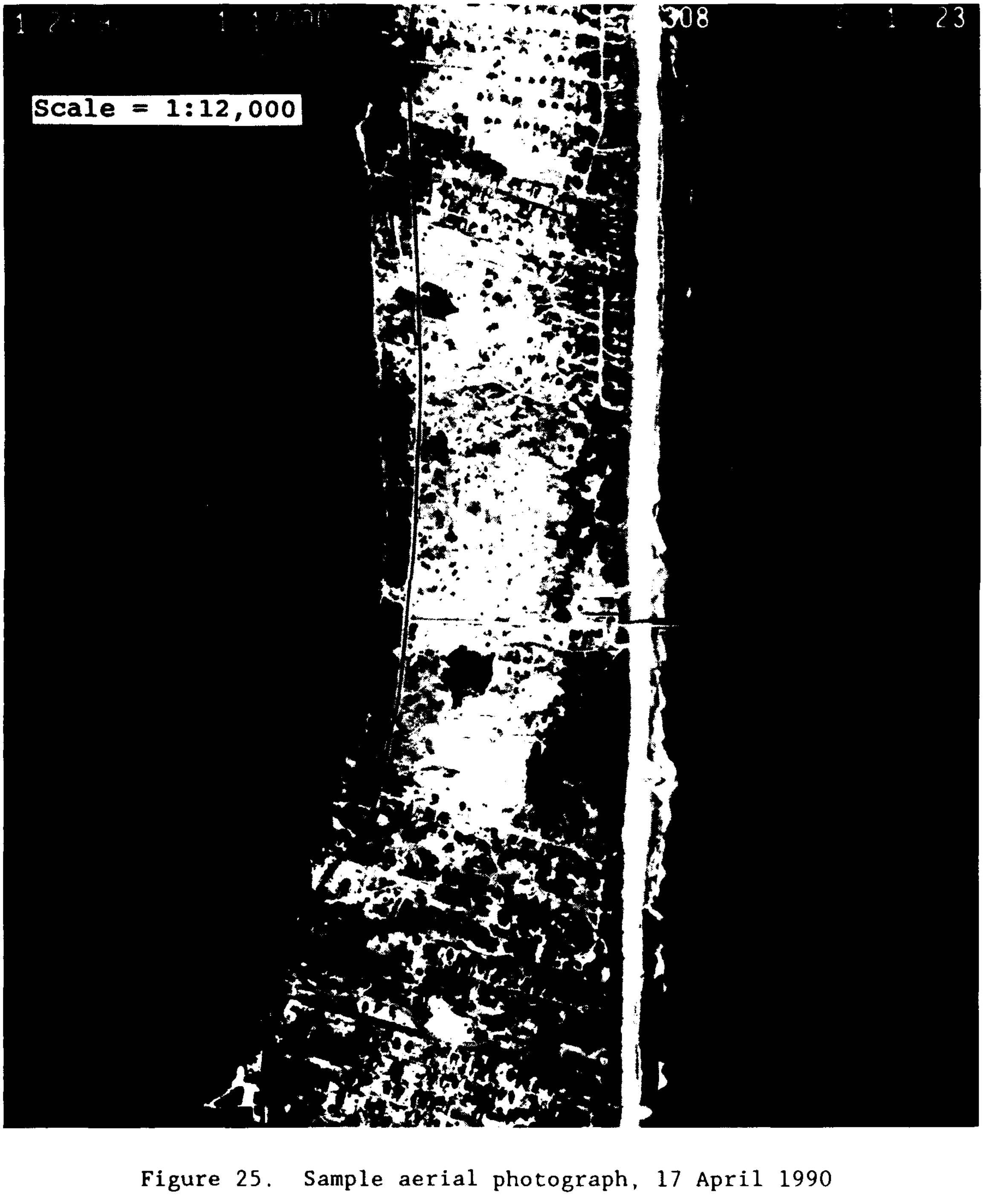
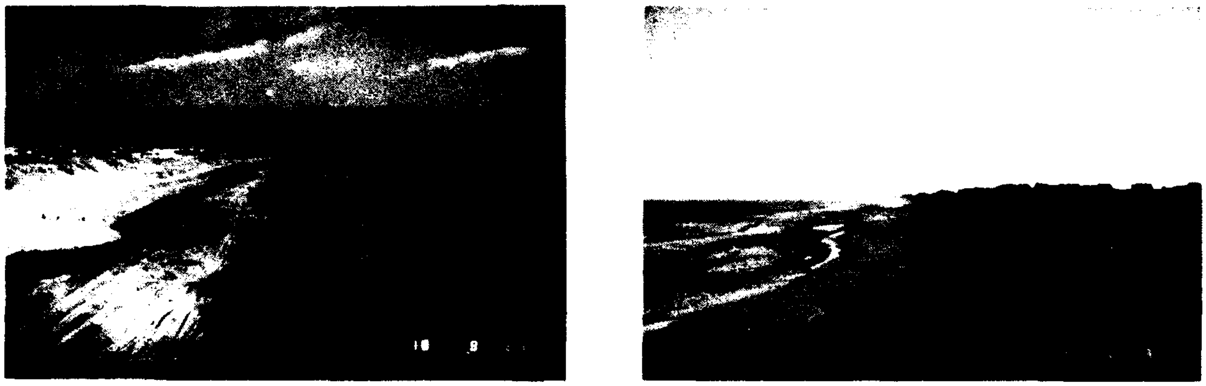


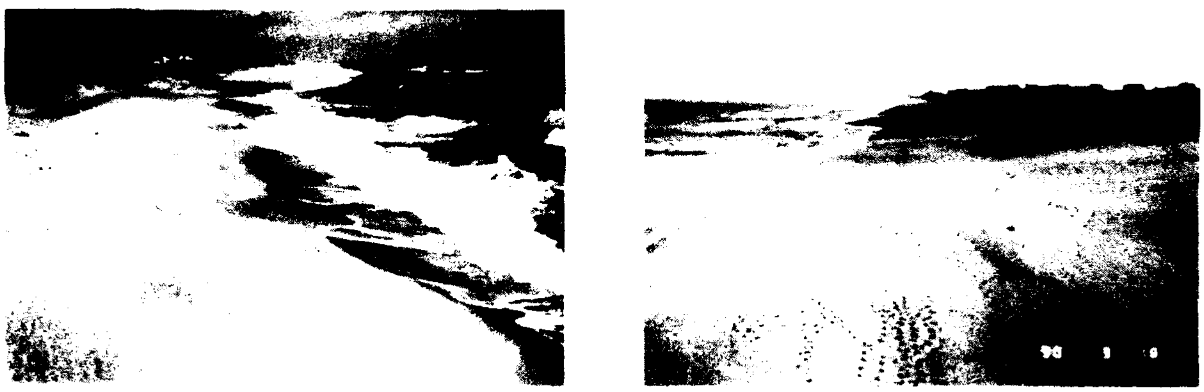
Figure 25. Sample aerial photograph, 17 April 1990

North View South View



a. 18 January 1990

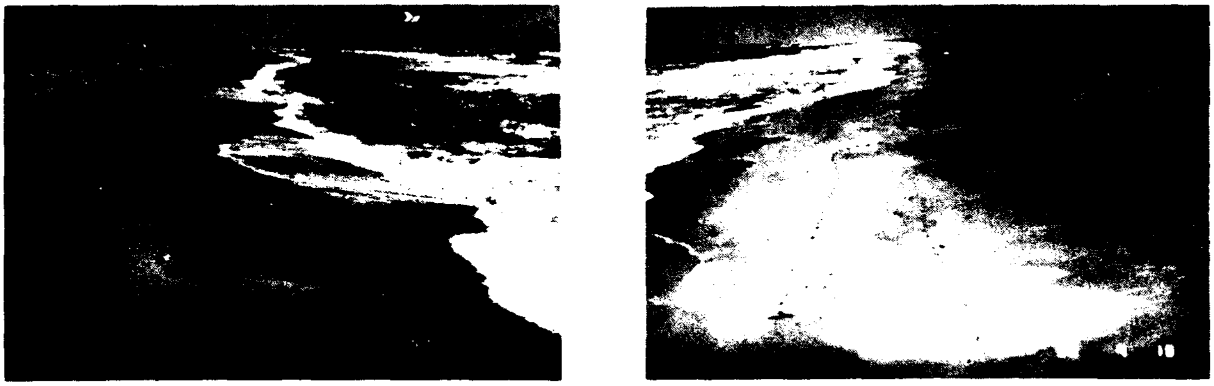
b. 18 February 1990



c. 18 March 1990

Figure 26. Beach photos looking north and south from the FRF pier (Sheet 1 of 4)

North View South View



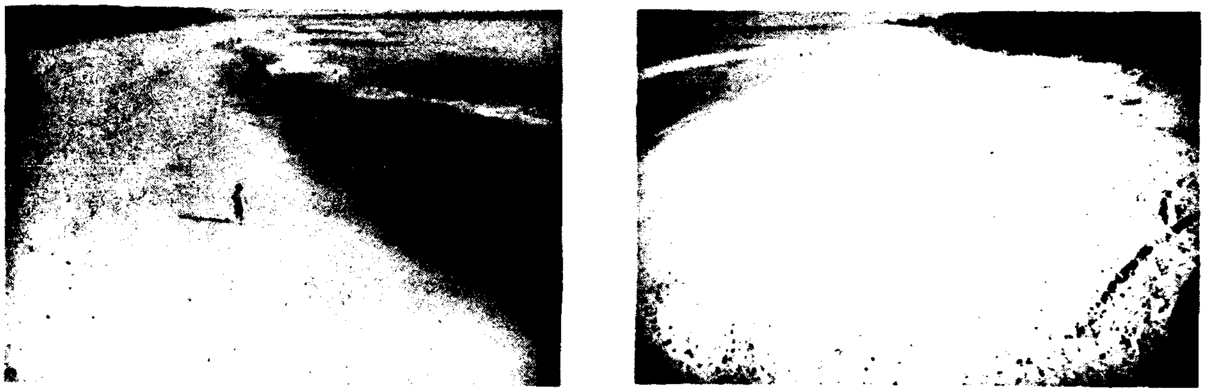
d. 18 April 1990

e. 18 May 1990

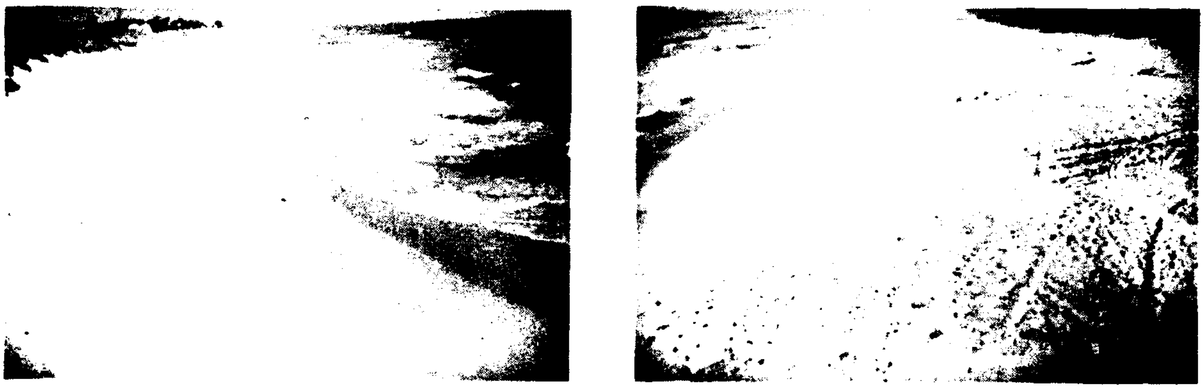
f. 28 June 1990

Figure 26. (Sheet 2 of 4)

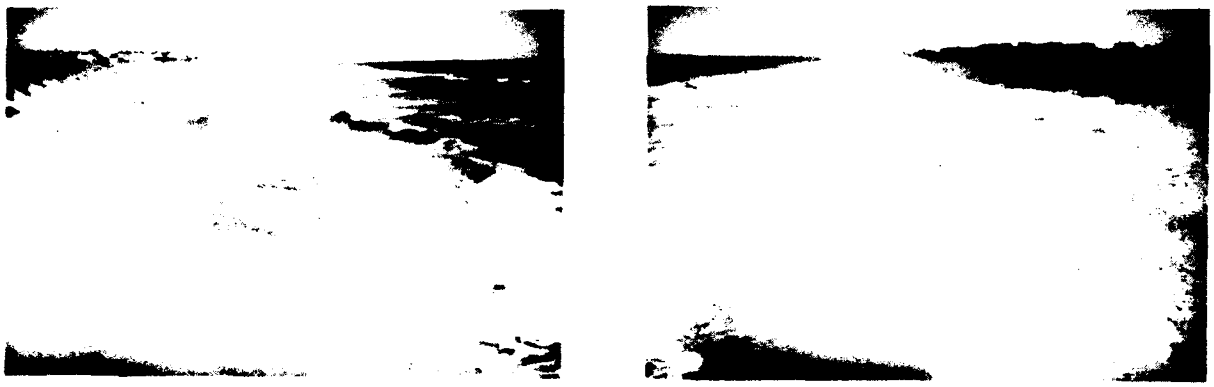
North View South View



g. 18 July 1990



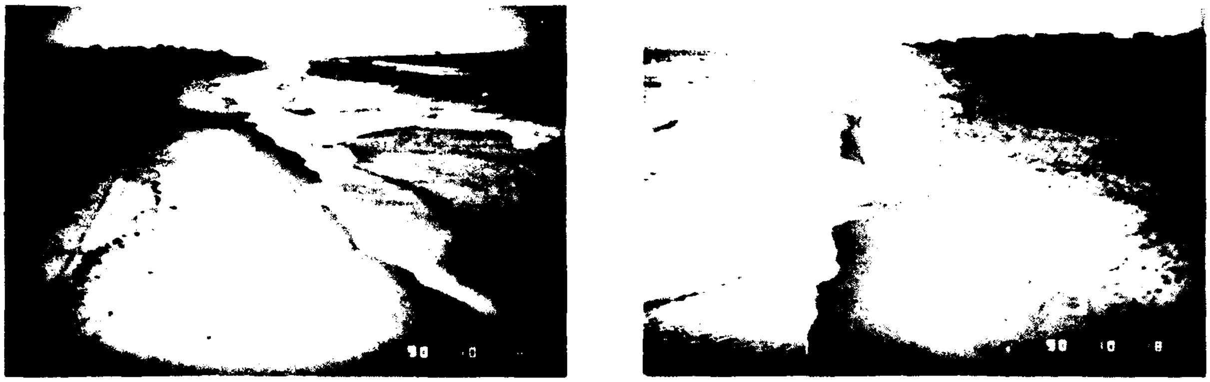
h. 28 August 1990



i. 18 September 1990

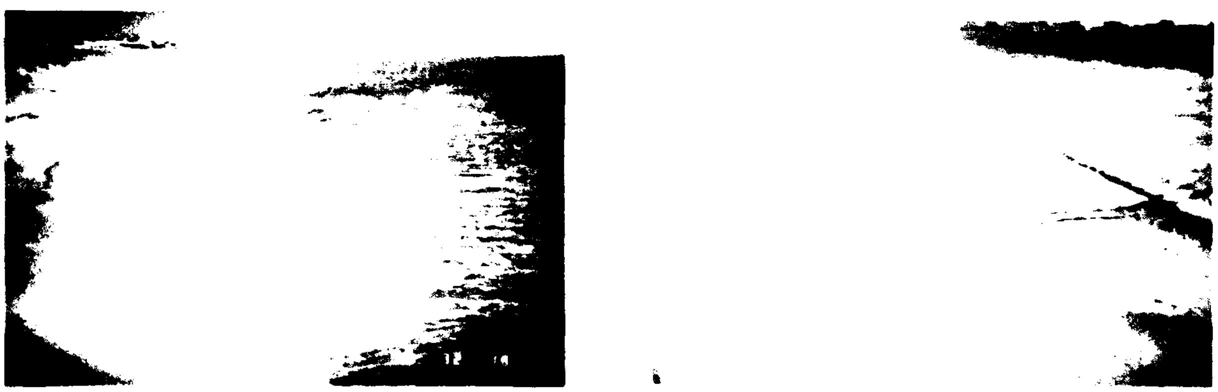
Figure 26. (Sheet 3 of 4)

North View South View



j. 18 October 1990

k. 18 November 1990



l. 18 December 1990

Figure 26. (Sheet 4 of 4)

PART IX: STORMS

64. This section discusses storms (defined here as times when the wave height parameter, H_{mo} , equaled or exceeded 2 m at the seaward end of the FRF pier). Sample spectra from Gage 630 are given in Appendix B. Prestorm and/or poststorm bathymetry diagrams are given in Appendix A. Tracking information was provided by NOAA Daily Weather Maps (US Department of Commerce 1990).

5 February 1990 (Figure 27)

65. Following the passage of a cold front, strong northerly winds generated by a high pressure system began to affect the FRF late on 4 February. Peak northerly winds exceeding 19 m/sec were recorded at 2200 EST on 4 February. The maximum H_{mo} (Gage 625) of 2.07 m (T_p = 7.31 sec) occurred at 0508 EST on 5 February.

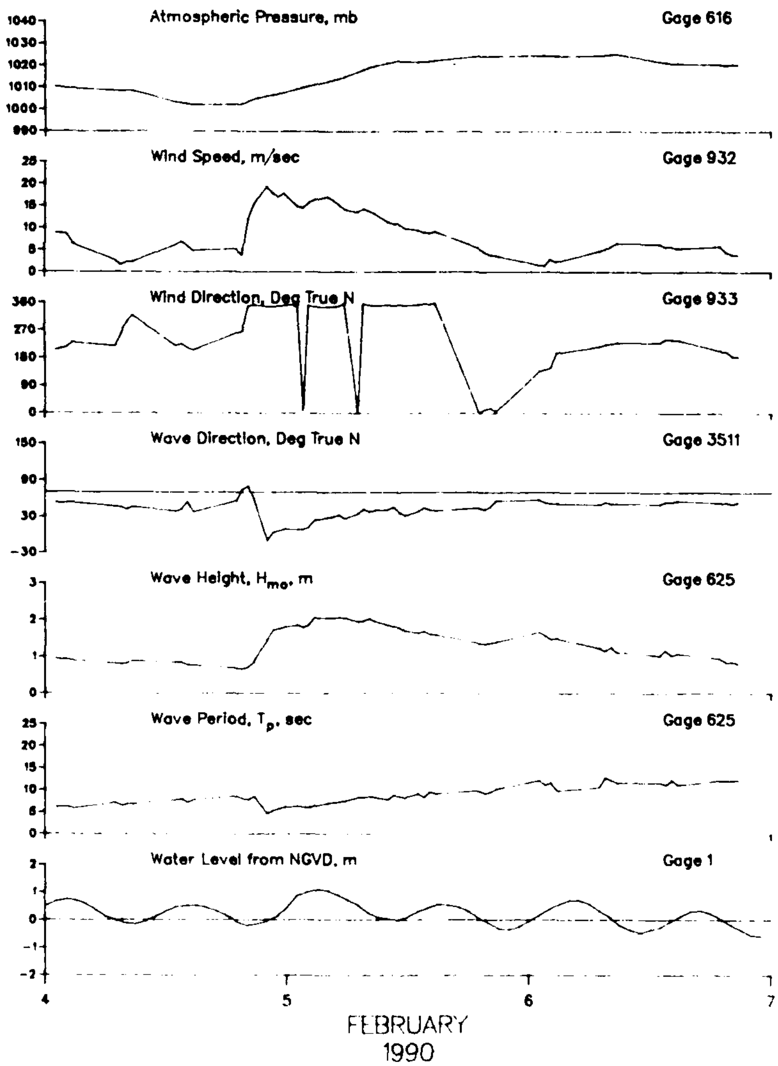


Figure 27. Data for 5 February 1990 storm

6 March 1990 (Figure 28)

66. Winds from a strong Canadian high pressure system began to generate storm waves at the FRF late on 6 March. The maximum H_{mo} (Gage 625) of 2.50 m (T_p = 7.53 sec) was attained at 0208 EST on 7 March. Maximum winds (from northeast) exceeding 16 m/sec occurred at 0542 EST also on 7 March.

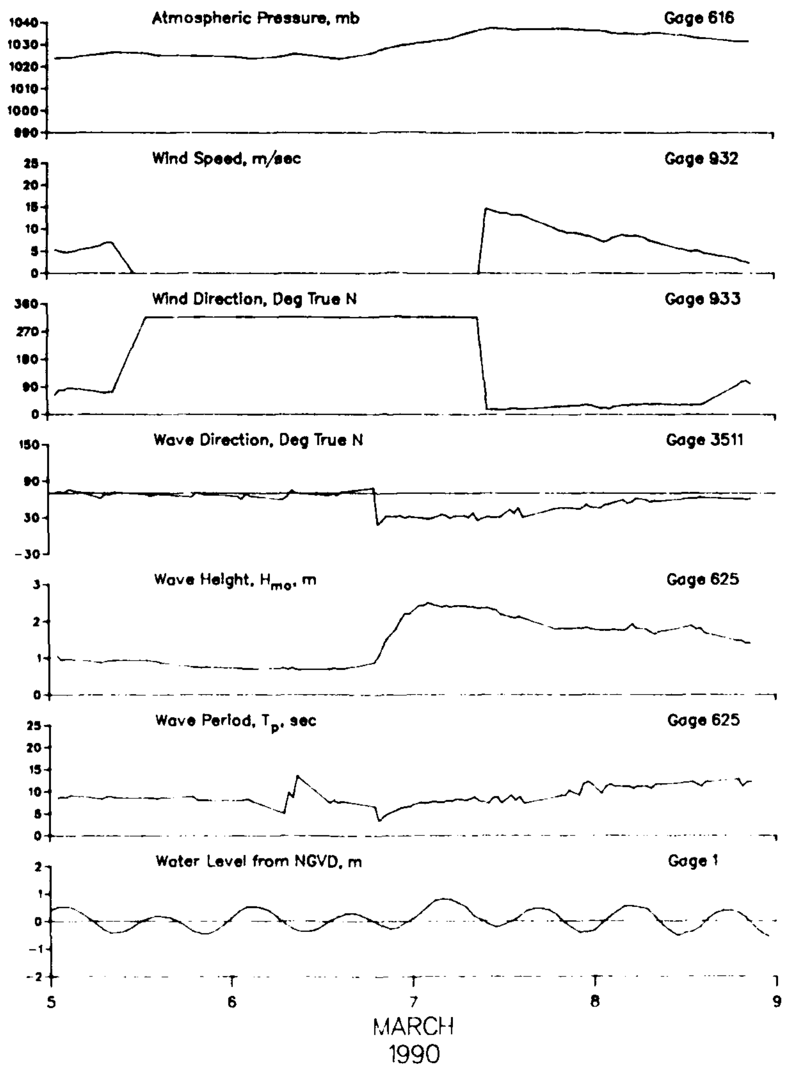


Figure 28. Data for 6 March 1990 storm

29 March 1990 (Figure 29)

67. Developing over South Carolina on 29 March, this storm rapidly moved to the northeast being located off the Virginia coast by 30 March. Maximum winds approaching 16 m/sec peaked at 1634 EST on 29 March with the maximum H_{mo} (Gage 625) of 2.22 (T_p = 6.92 sec) occurring later the same day at 1934 EST. The minimum atmospheric pressure of 1,014 mb was recorded at 0400 EST on 30 March. Total precipitation was 30 mm.

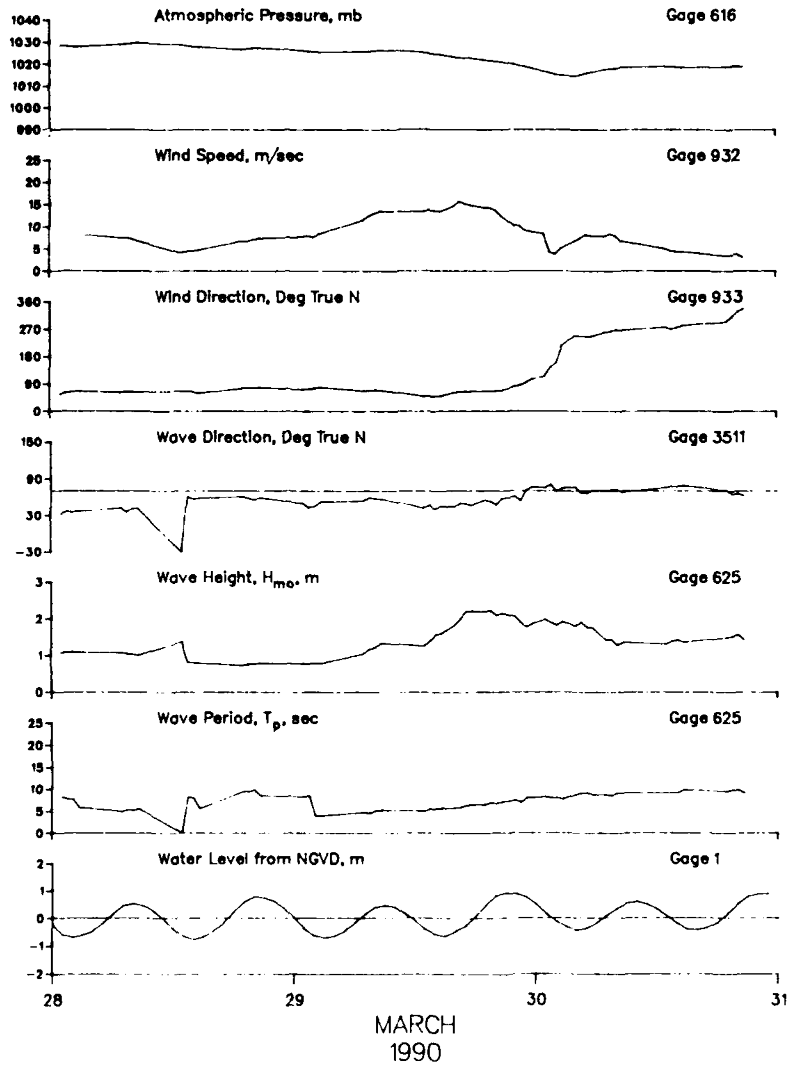


Figure 29. Data for 29 March 1990 storm

22-23 May 1990 (Figure 30)

68. Traveling across the southern United States, this storm went off the South Carolina coast early on 23 May. The maximum H_{mo} (Gage 625) of 2.33 m (T_p = 6.92 sec) was attained at 2222 EST on 22 May. Preceding this by several hours, the peak wind speed (from northeast) exceeded 16 m/sec. Because the storm track remained well south of the FRF, the minimum atmospheric pressure dropped to only 1,007.1 mb. Total precipitation was 45 mm.

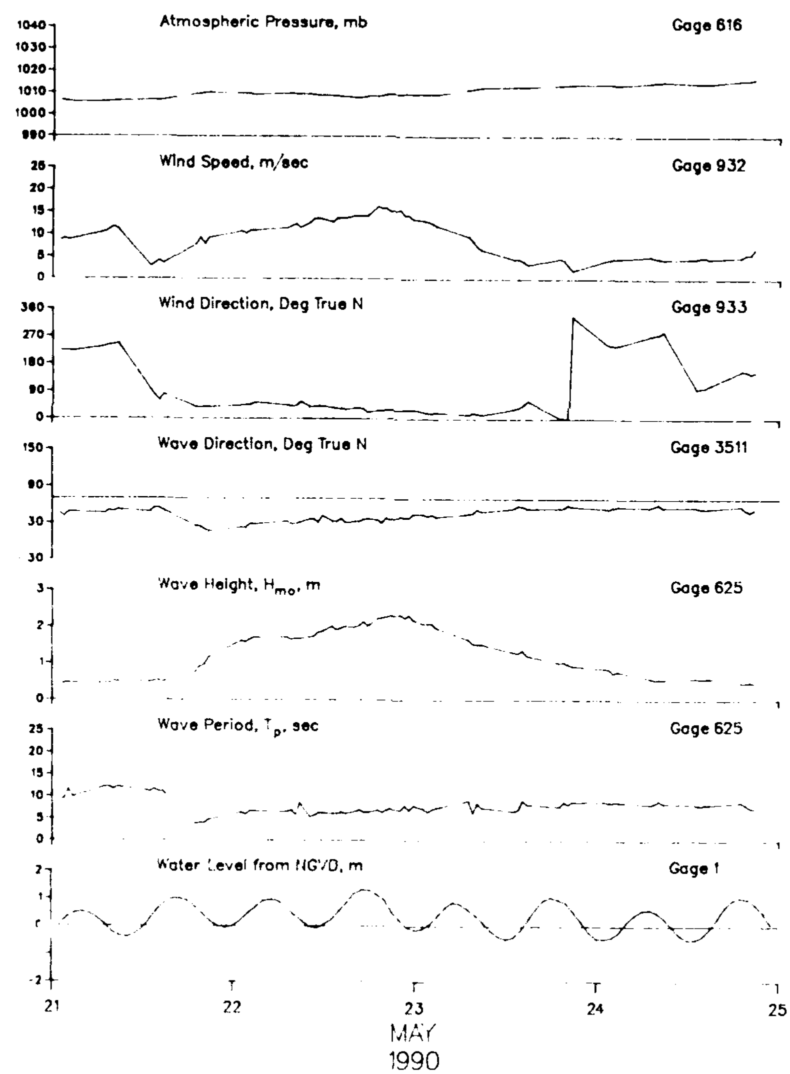


Figure 30. Data for 22-23 May 1990 storm

12-13 October 1990 (Figure 31)

69. Large waves generated by Hurricane Lili arrived on the North Carolina coast late on 12 October. Remaining well offshore, Lili turned north on 13 October, no longer posing a threat to the coast. Because the storm remained well offshore, the only effects to the FRF were the increased wave heights. The maximum H_{mo} (Gage 625) of 2.44 m (T_p = 12.88 sec) occurred at 2133 EST on 12 October.

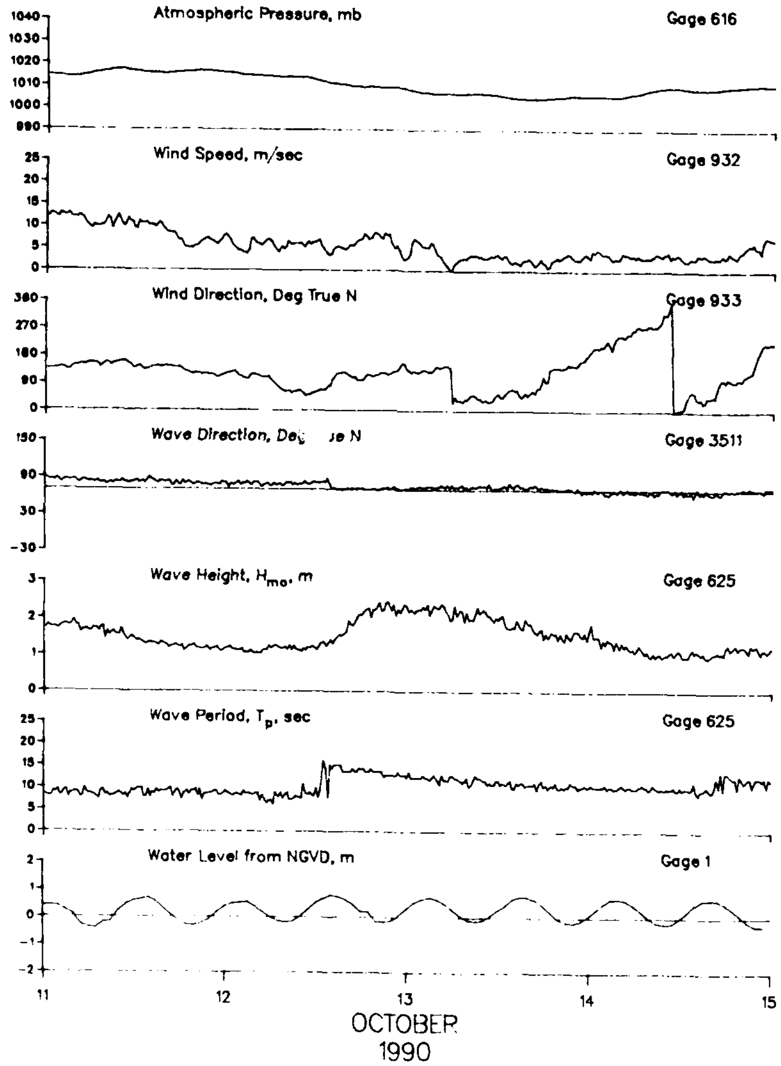


Figure 31. Data for 12-13 October 1990 storm

25-27 October 1990 (Figure 32)

70. Forming over South Carolina early on 25 October, this strong storm slowly moved offshore where it quickly intensified and slowly moved up the coast, being centered off Cape Hatteras, NC, on the morning of 26 October. By 27 October the storm was located off New England. Peak winds approaching 21 m/sec were recorded at 0434 EST on 26 October with the maximum H_{mo} (Gage 111) of 5.00 m (T_p = 9.85 sec) occurring several hours later at 0700 EST. The minimum atmospheric pressure of 992.3 mb was recorded on 26 October at 0259 EST. Total precipitation was 43 mm.

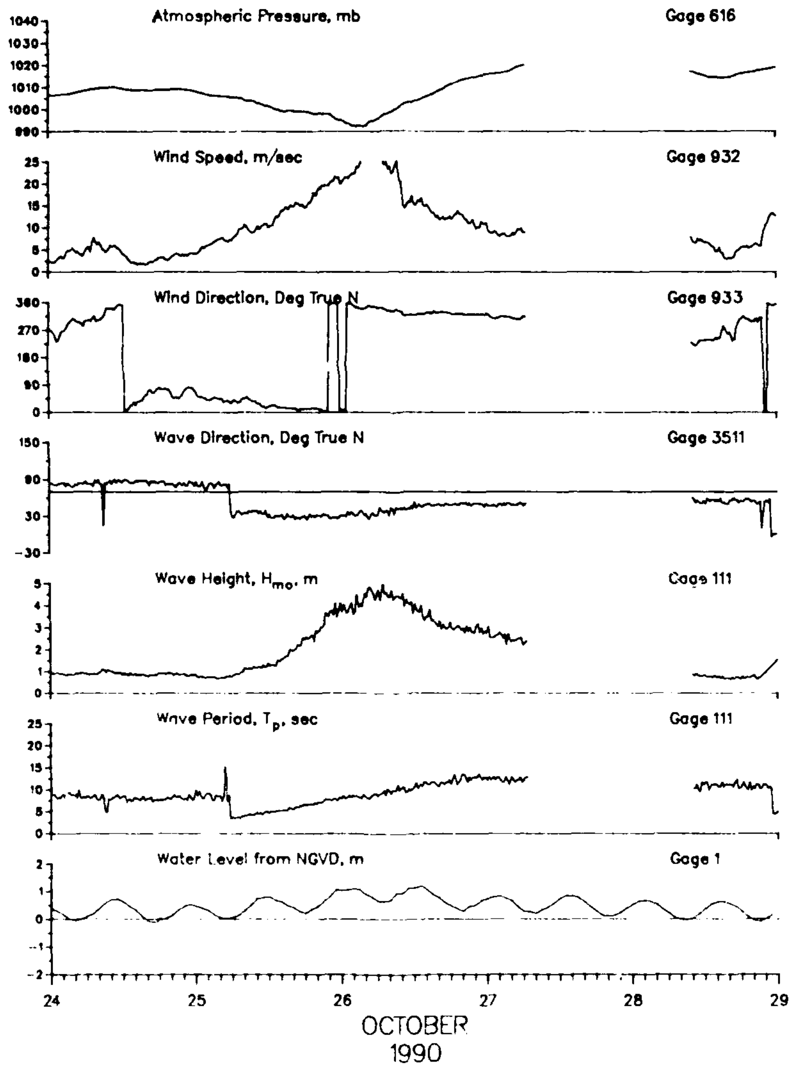


Figure 32. Data for 25-27 October 1990 storm

10 November 1990 (Figure 33)

71. Developing over Texas early on 8 November, this storm quickly moved to the east, being located over North Carolina on 10 November. Maximum wind speeds (from southeast) exceeded 13 m/sec at 0508 EST on 10 November. The peak H_{mo} (Gage 625) reached 2.62 m (T_p = 9.85 sec) several hours later at 0734 EST. The minimum atmospheric pressure of 996.6 mb occurred at 0633 EST, also on 10 November. Total precipitation was 34 mm.

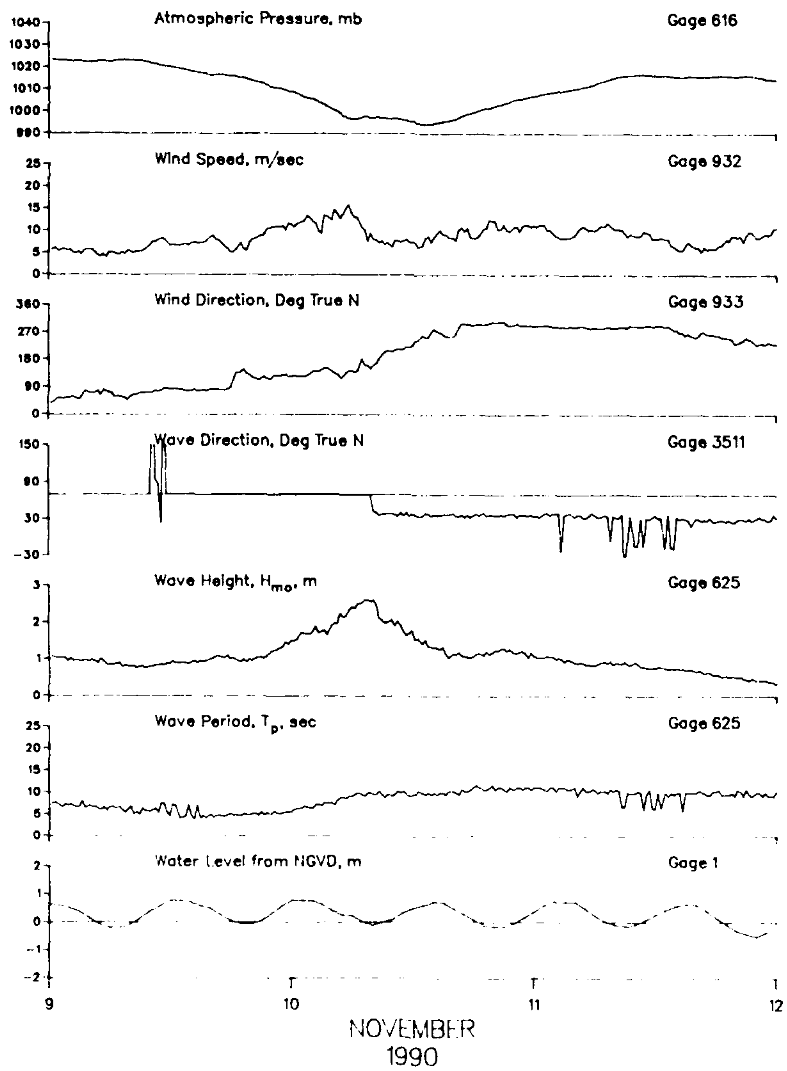


Figure 33. Data for 10 November 1990 storm

17-19 November 1990 (Figure 34)

72. Strong winds generated by a mid-western high pressure system began to produce storm waves at the FRF late on 17 November. Maximum wind speeds (from north) exceeded 16 m/sec at 2308 EST on 17 November. The peak H_{mo} (at Gage 625) reached 2.37 m (T_p = 7.76 sec) at 0134 EST on 18 November.

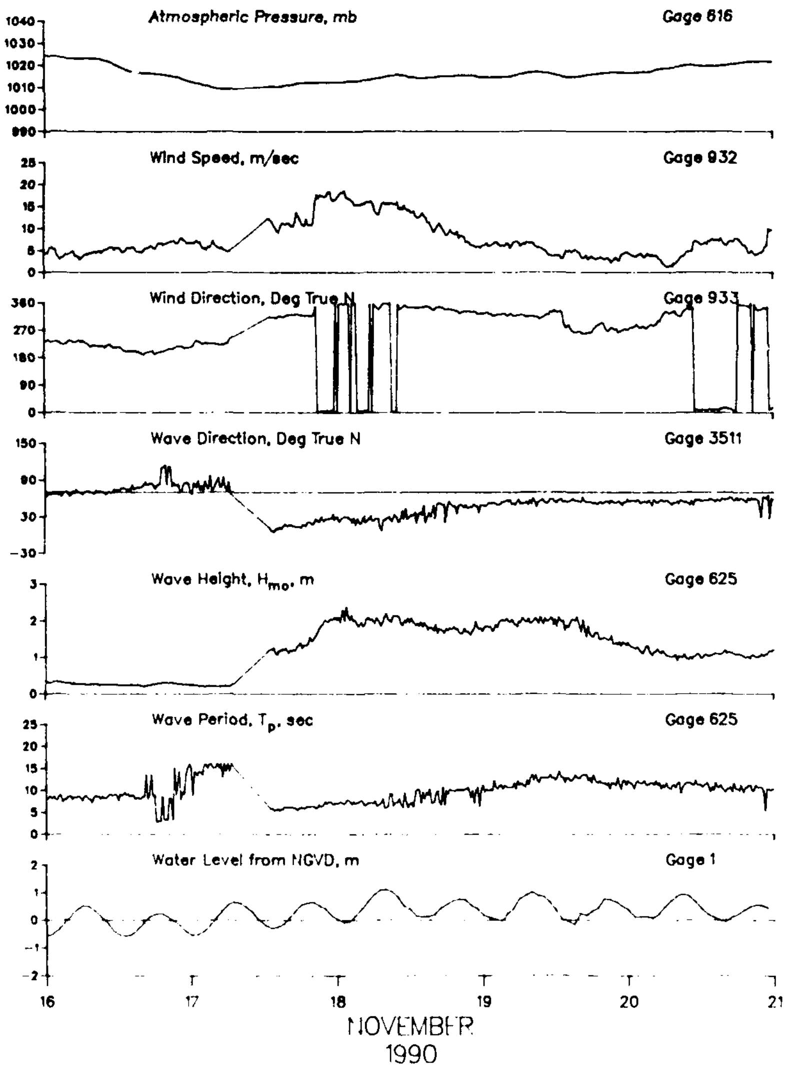


Figure 34. Data for 17-19 November 1990 storm

30 November 1990 (Figure 35)

73. Following the passage of a cold front early on 29 November, strong winds generated by another mid-western high pressure system briefly produced storm waves at the FRF. Winds exceeded 10 m/sec (from north-northwest) at 0100 EST on 30 November with the maximum H_{mo} (Gage 625) of 2.15 m (T_p = 6.92 sec) occurring at the same time.

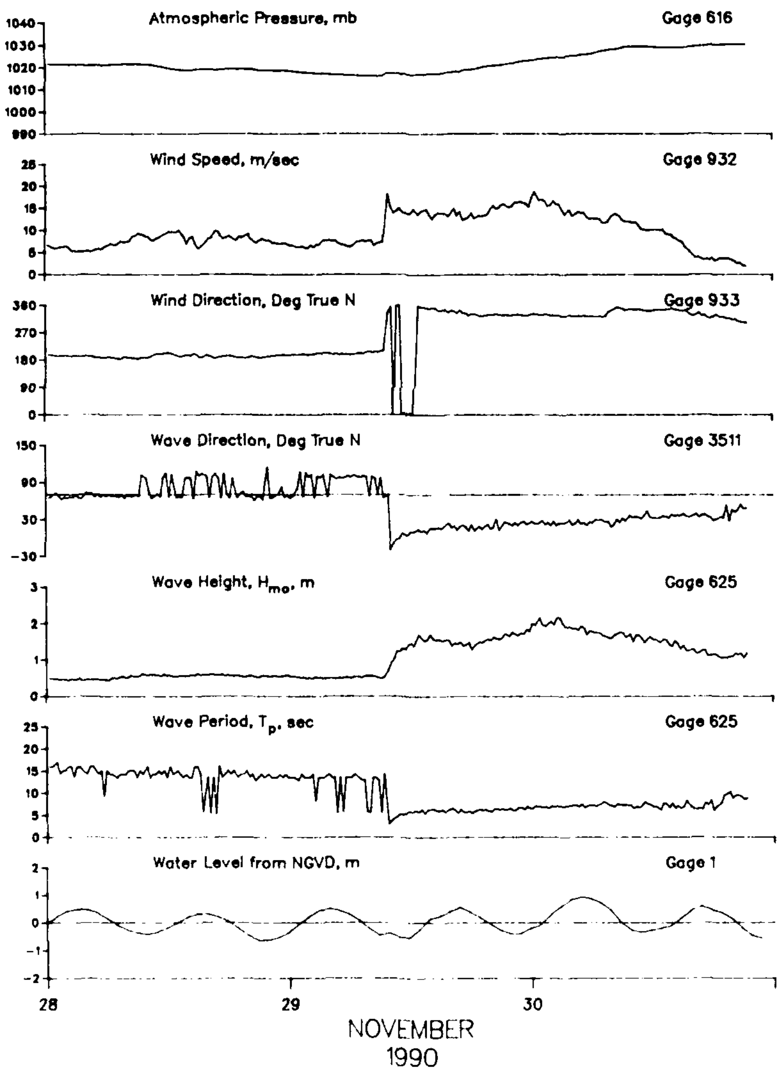


Figure 35. Data for 30 November 1990 storm

8-9 December 1990 (Figure 36)

74. Developing over Texas on 6 December, this small coastal storm rapidly moved into the Atlantic, being located off Cape Hatteras, NC, on 8 December. The minimum atmospheric pressure of 1,010.0 mb was recorded on 8 December at 1442 EST followed (at 1600 EST) by the peak wind speed (from north-northwest) which surpassed 15 m/sec. The maximum H_{mo} (Gage 625) of 2.08 m (T_p = 9.48 sec) occurred on 9 December at 0542 EST. Total precipitation was 24 mm.

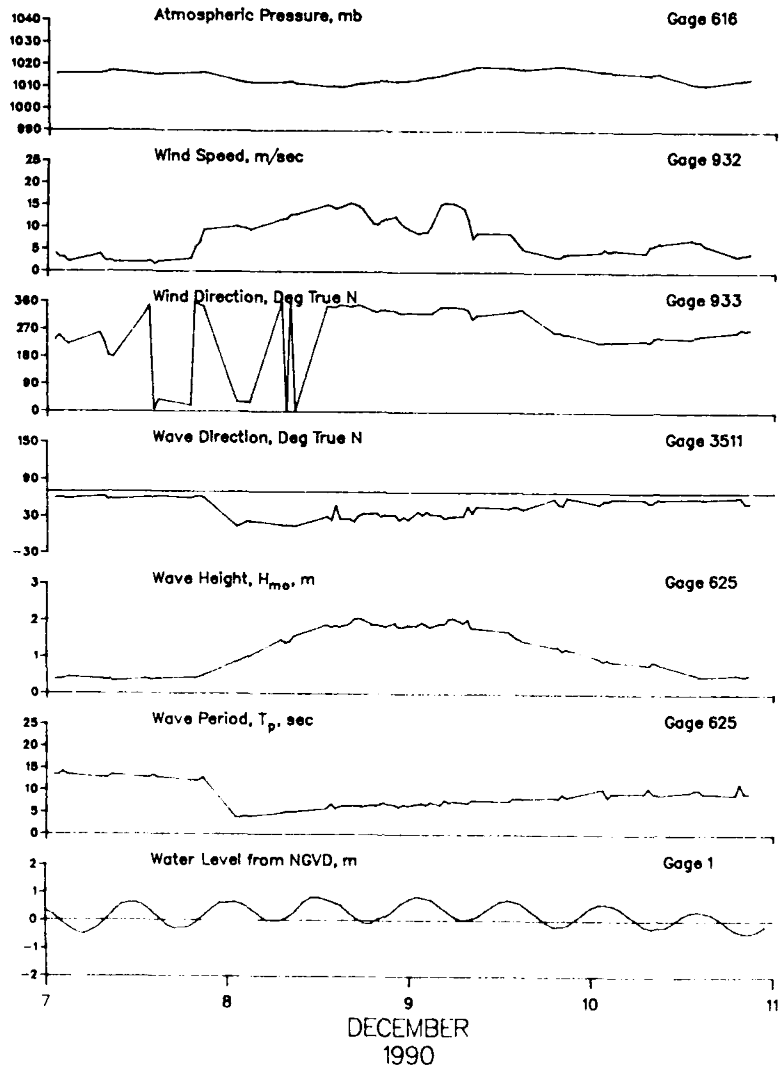


Figure 36. Data for 8-9 December 1990 storm

REFERENCES

Bingham, C., Godfrey, M. D., and Tukey, J. W. 1967. "Modern Techniques of Power Spectrum Estimation," IEEE Trans. Audio Electroacoustics, AU-15, pp 56-66.

Birkemeier, W. A., and Mason, C. 1984. "The CRAB: A Unique Nearshore Surveying Vehicle," Journal of Surveying Engineering, American Society of Civil Engineers, Vol 110, No. 1.

Field Research Facility. 1990 (Jan-Dec). "Preliminary Data Summary," Monthly Series, Coastal Engineering Research Center, US Army Engineer Waterways Experiment Station, Vicksburg, MS.

Grogg, W. E., Jr. 1986. "Calibration and Stability Characteristics of the Baylor Staff Wave Gage," Miscellaneous Paper CERC-86-7, US Army Engineer Waterways Experiment Station, Vicksburg, MS.

Miller, H. C. 1980. "Instrumentation at CERC's Field Research Facility, Duck, North Carolina," CERC Miscellaneous Report 80-8, US Army Engineer Waterways Experiment Station, Vicksburg, MS.

Miller, H. C., Birkemeier, W. A., and DeWall, A. E. 1983. "Effect of the CERC Research Pier on Nearshore Processes," Coastal Structures '83, American Society of Civil Engineers, Arlington, VA, pp 769-785.

US Department of Commerce. 1987. "Daily Weather Maps," Weekly Series, Washington, DC.

Welch, P. D. 1967. "The Use of Fast Fourier Transform for the Estimation of Power Spectra: A Method Based on Time Averaging Over Short Modified Periodograms," IEEE Trans. Audio Electroacoustics, AE-15, pp 70-73.

APPENDIX A: SURVEY DATA

1. Contour diagrams constructed from the bathymetric survey data are presented in this appendix. The profile lines surveyed are identified on each diagram. Contours are in half meters referenced to the National Geodetic Vertical Datum (NGVD). The distance offshore is referenced to the Field Research Facility (FRF) monumentation baseline behind the dune.

2. Changes in FRF bathymetry diagrams constructed by contouring the difference between two contour diagrams are also presented with contour intervals of 0.25 m. Wide contour lines show areas of erosion. Other areas correspond to areas of accretion. Although these change diagrams are based on considerable interpolation of the original survey data, they do facilitate comparison of the contour diagrams.

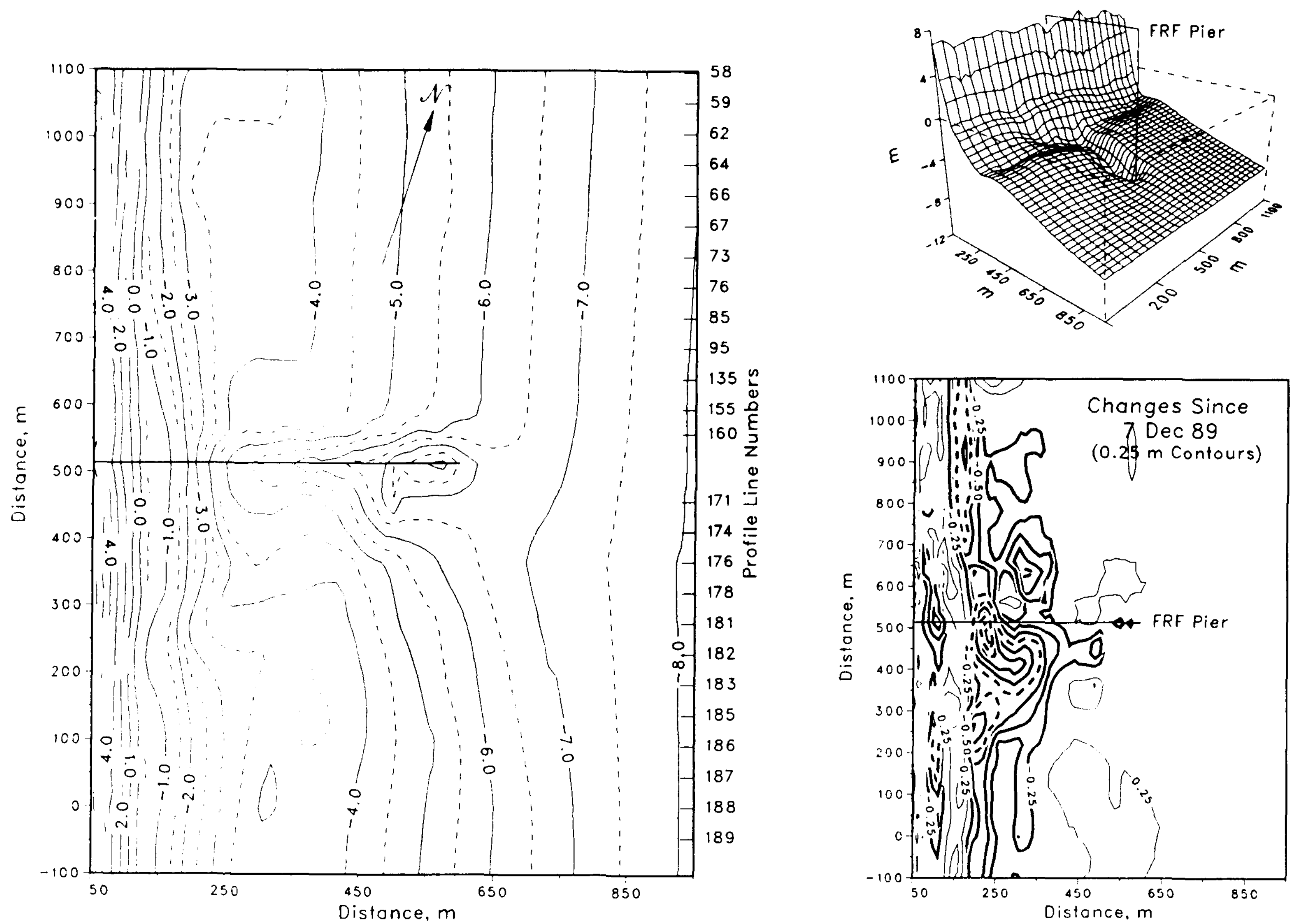


Figure A1. FRF Bathymetry 29 January 90 (depths relative to NGVD)

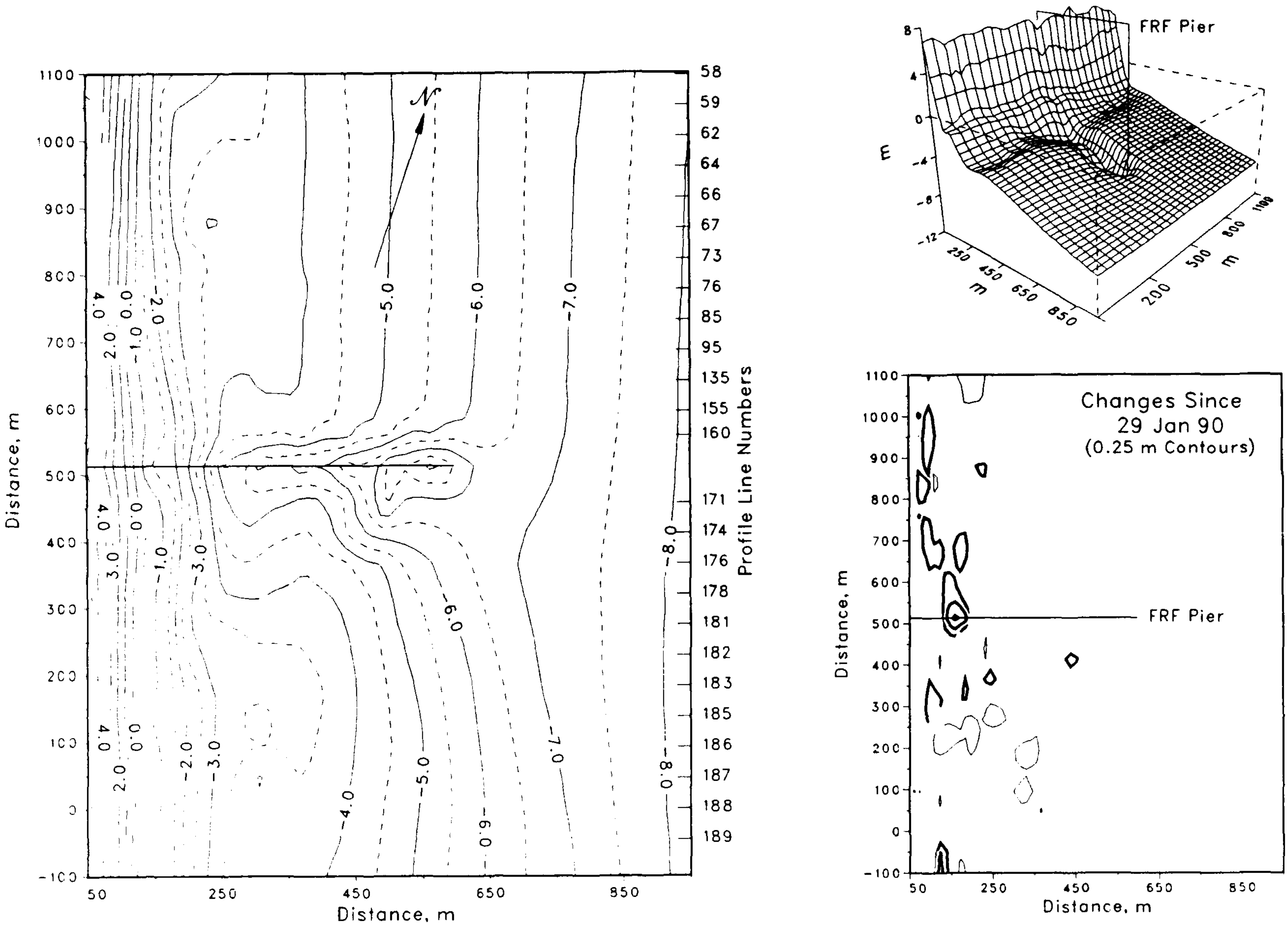


Figure A2. FRF Bathymetry 16 February 90 (depths relative to NGVD)

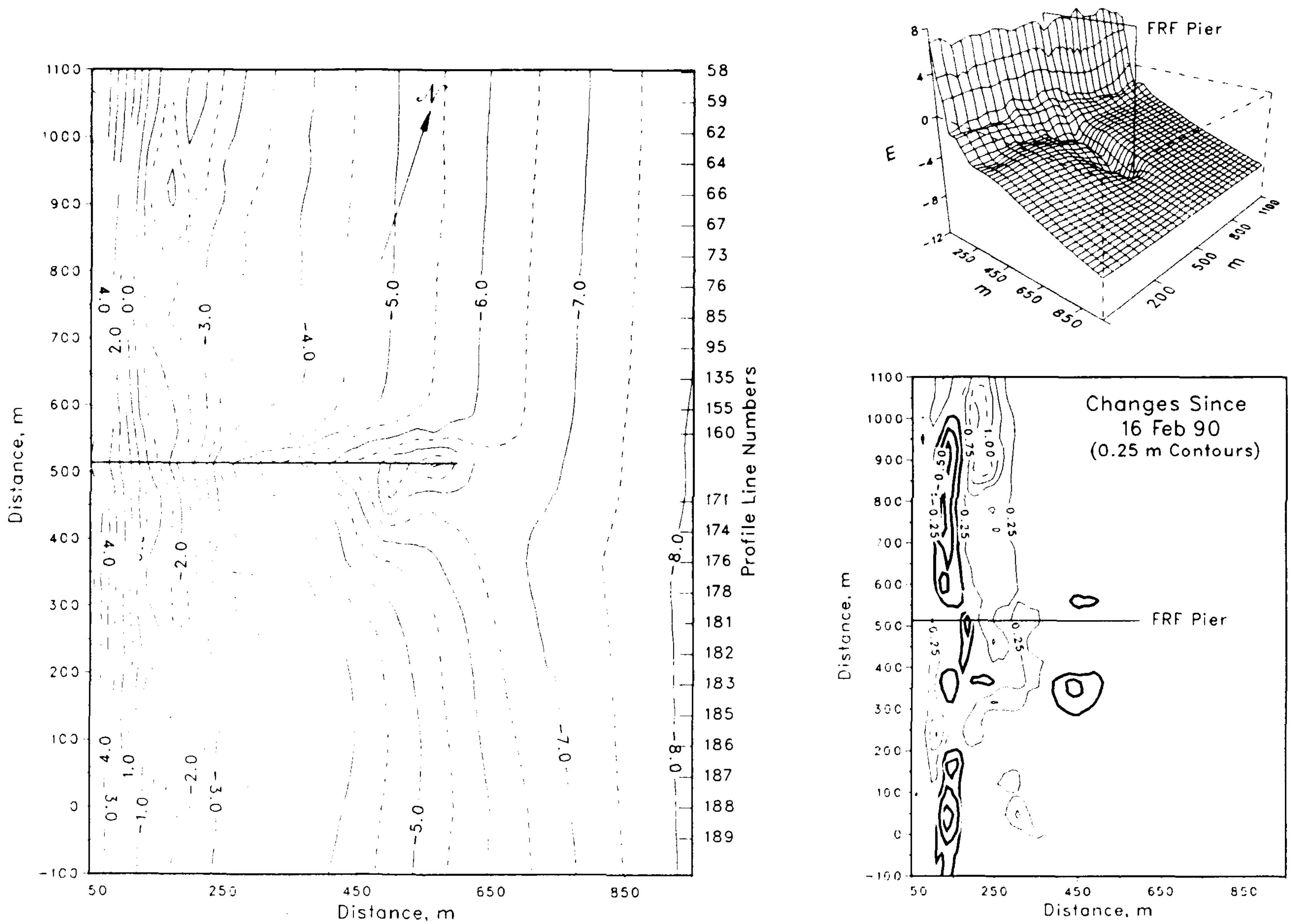


Figure A3. FRF Bathymetry 19 March 90 (depths relative to NGVD)

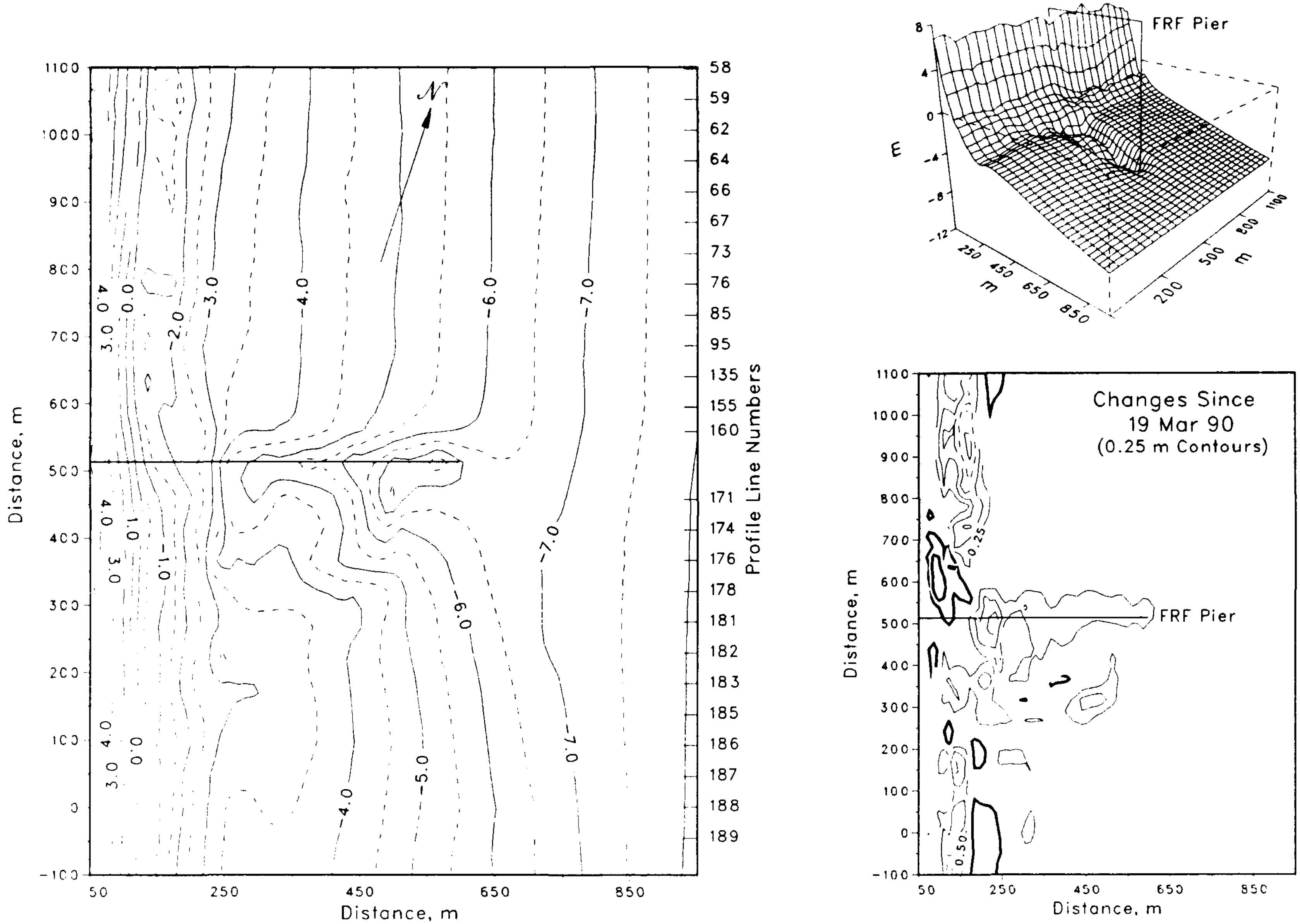


Figure A4. FRF Bathymetry 8 May 90 (depths relative to NGVD)

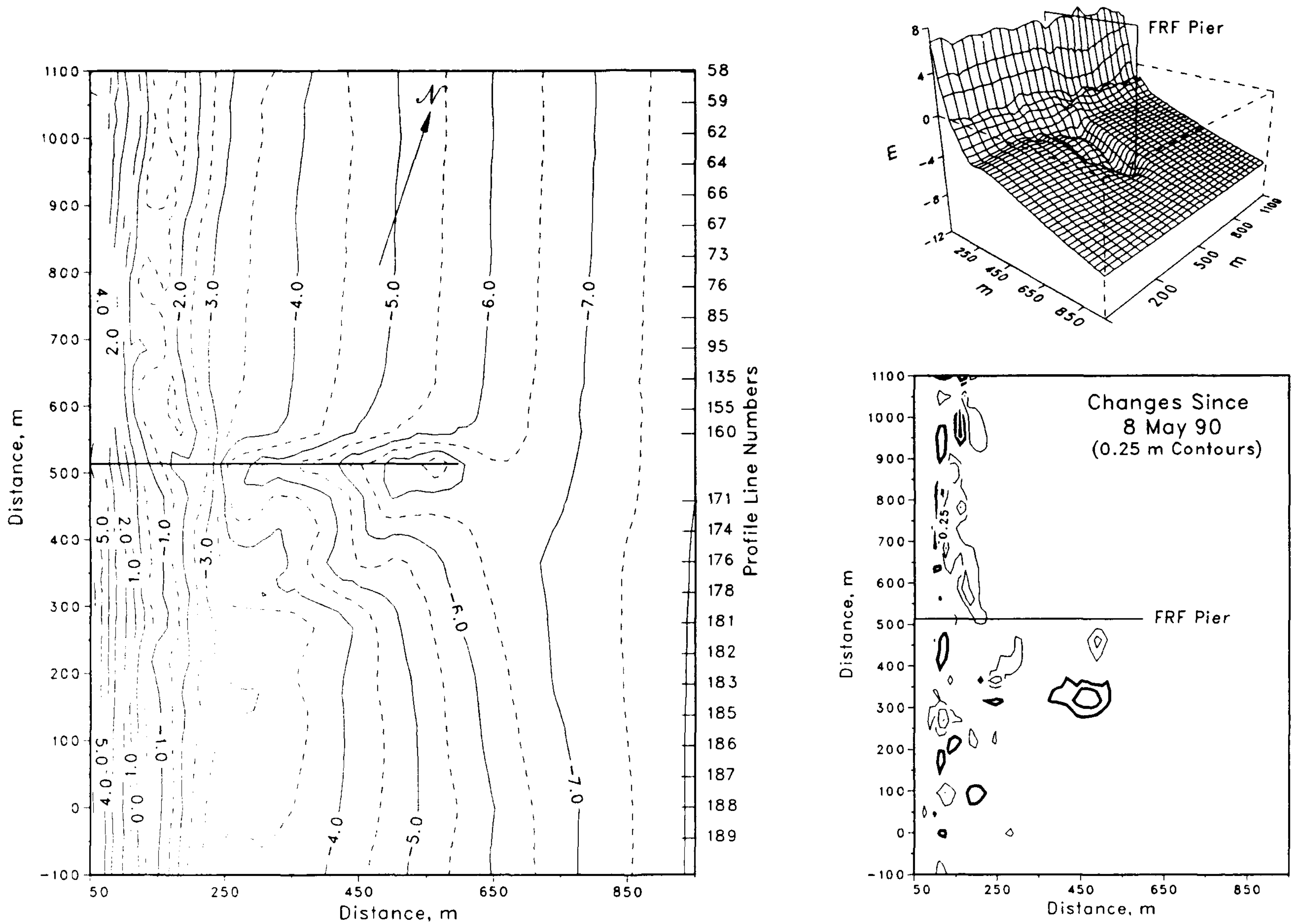


Figure A5. FRF Bathymetry 27 June 90 (depths relative to NGVD)

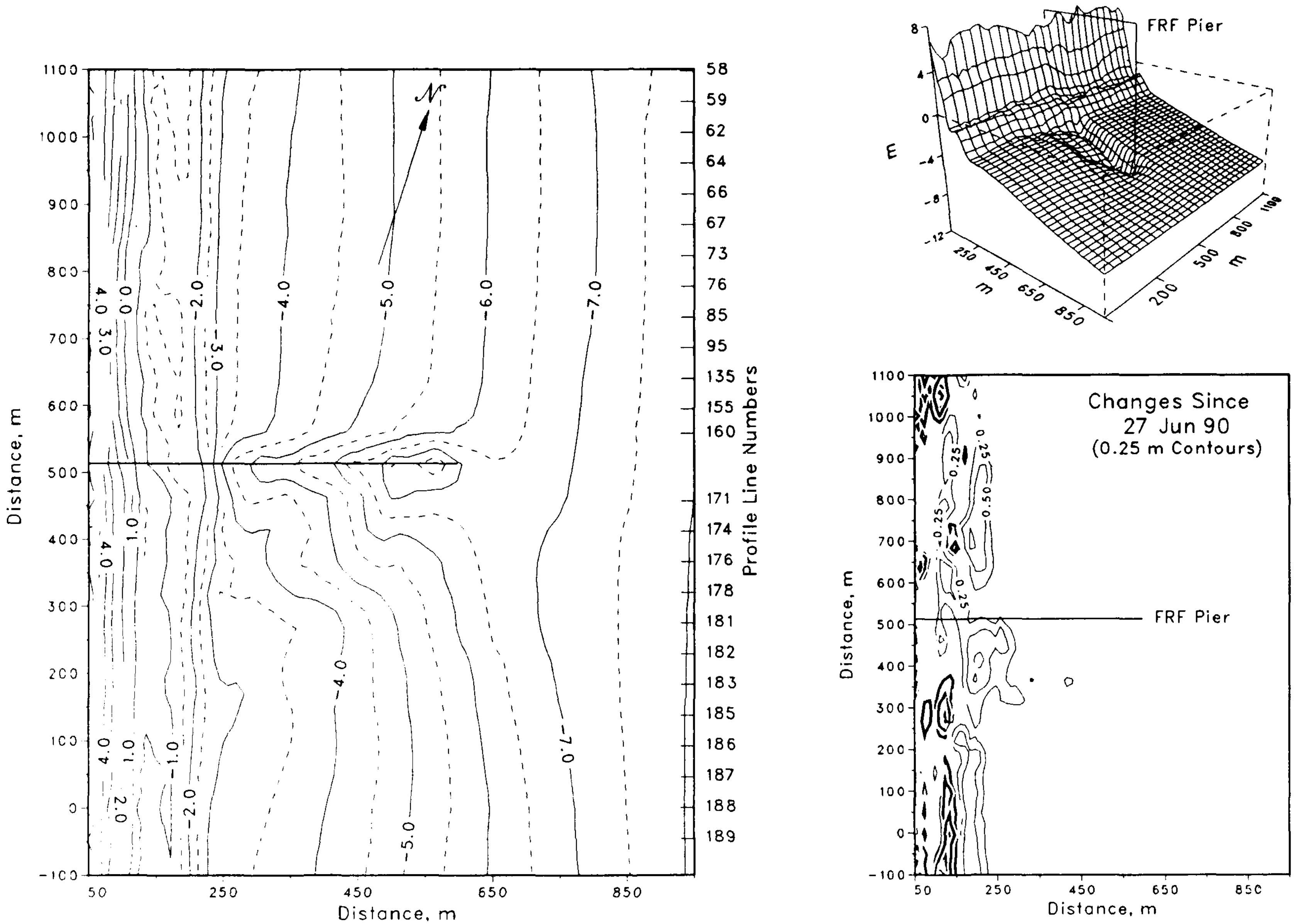


Figure A6. FRF Bathymetry 6 September 90 (depths relative to NGVD)

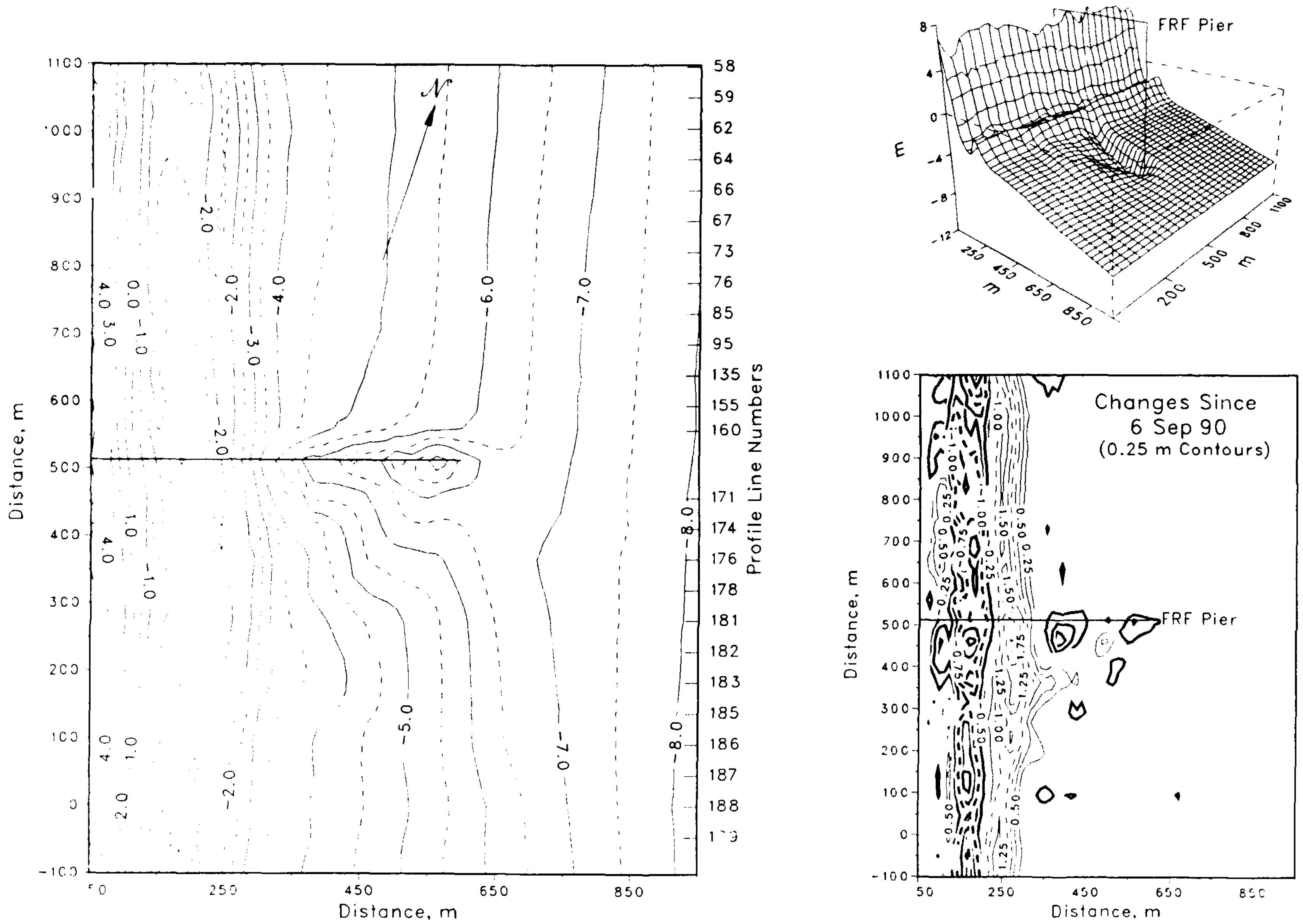


Figure A7. FRF Bathymetry 31 October 90 (depths relative to NGVD)

APPENDIX B: WAVE DATA FOR GAGE 630

1. Wave data summaries for Gage 630 are presented for 1990 and for 1980 through 1990 in the following forms:

Daily H_{mo} and T_p

2. Figure B1 displays the individual wave height (H_{mo}) and peak spectral wave period (T_p) values along with the monthly mean values.

Joint Distributions of H_{mo} and T_p

3. Annual and monthly joint distributions tables are presented in Tables B1 and B2, and data for 1980 through 1990 are in Tables B3 and B4. Each table gives the frequency (in parts per 10,000) for which the wave height and peak period were within the specified intervals; these values can be converted to percentages by dividing by 100. Marginal totals are also included. The row total gives the number of observations out of 10,000 that fell within each specified peak period interval. The column total gives the number of observations out of 10,000 that fell within each specified wave height interval.

Cumulative Distributions of Wave Height

4. Annual and monthly wave height distributions for 1990 are plotted in cumulative form in Figures B2 and B3. Data for 1980 through 1990 are in Figure B4.

Peak Spectral Wave Period Distributions

5. Annual and monthly peak wave period, T_p, distribution histograms for 1990 are presented in Figures B5 and B6. Data for 1980 through 1990 are in Figure B7.

Persistence of Wave Heights

6. Table B5 shows the number of times in 1990 when the specified wave height was equaled or exceeded at least once during each day for the duration (consecutive days). Data for 1980 through 1990 are given in Table B6. An example is shown below:

Height	Consecutive Day(s) or Longer																		
m	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19+
0.5	18	15		14	13	12		11	10	9				8		7			
1.0	50	34	24	21	18	14	12	8	7	3			2						
1.5	41	19	8	6	2	1													
2.0	22	9	5	1															
2.5	10	5	2																
3.0	6	1																	
3.5		1																	
4.0	1																		

This example indicates that wave heights equaled or exceeded 1.0 m 50 times for at least 1 day; 34 times for at least 2 days; 24 times for at least 3 days, etc. Therefore, on 16 occasions the height equaled or exceeded 1.0 m for 1 day exactly (50 - 34 = 16); on 10 occasions for 2 days; on 3 occasions for 3 days, etc. Note that the height exceeded 1 m 50 times for 1 day or longer, while heights exceeded 0.5 m only 18 times for this same duration. This change in durations occurred because the longer durations of lower waves may be interspersed with shorter, but more frequent, intervals of higher waves. For example, one of the times that the wave heights exceeded 0.5 m for 16 days may have represented 3 times the height exceeded 1 m for shorter durations.

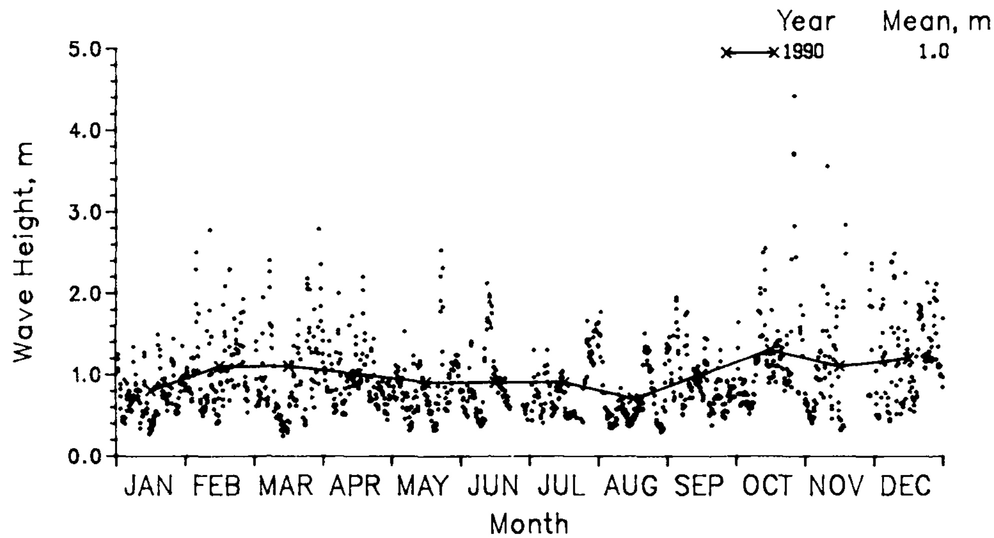
Spectra

7. Monthly spectra for the offshore Waverider buoy (Gage 630) are presented in Figure B8. The plots show "relative" energy density as a function of wave frequency. These figures summarize the large number of spectra for each month. The figures emphasize the higher energy density associated with storms as well as the general shifts in energy density to different frequencies. As used here, "relative" indicates the spectra have been smoothed by the three-dimensional surface drawing routine. Consequently, extremely high- and low-energy density values are modified to produce a smooth surface. The figures are not intended for quantitative measurements; however,

they do provide the energy density as a function of frequency relative to the other spectra for the month.

8. Monthly and annual wave statistics for Gage 630 for 1990 and for 1980 through 1990 are presented in Table B7.

9. Figure B9 plots monthly time-histories of wave height and period.



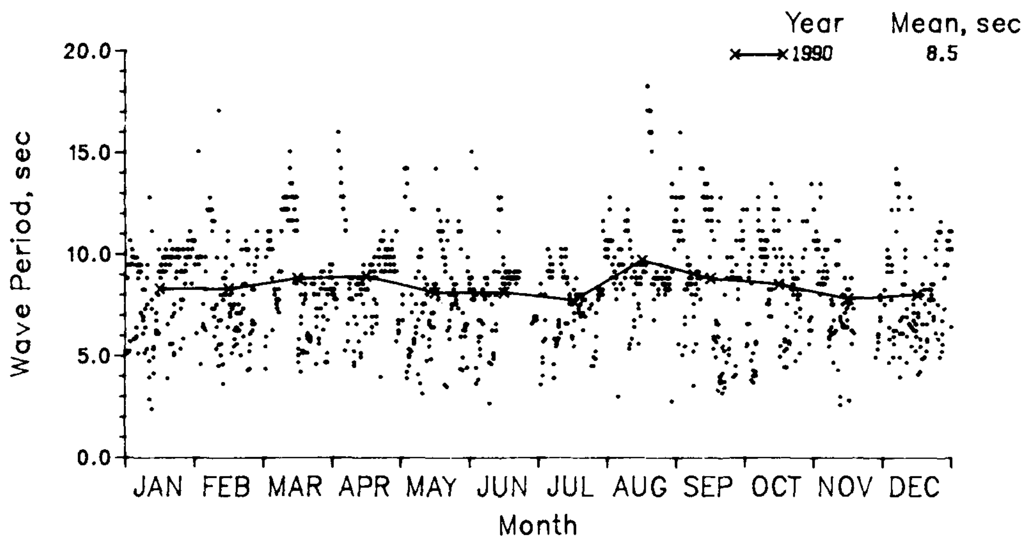


Figure B1. 1990 daily wave height and period values with monthly means for Gage 630

Table B1

Annual Joint Distribution of H_{mo} versus T_p

Annual 1990, Gage 630
Percent Occurrence(X100) of Height and Period

	Period, sec												
Height, m	2.0-2.9	3.0-3.9	4.0-4.9	5.0-5.9	6.0-6.9	7.0-7.9	8.0-8.9	9.0-9.9	10.0-11.9	12.0-13.9	14.0-15.9	16.0-Longer	Total
0.00 - 0.49	15	.	15	15	45	104	378	312	178	52	126	.	1240
0.50 - 0.99	45	163	237	401	497	490	1105	868	838	96	356	37	5133
1.00 - 1.49	.	15	230	445	312	178	482	289	297	37	134	.	2419
1.50 - 1.99	.	.	7	208	185	96	96	104	82	.	52	.	830
2.00 - 2.49	.	.	.	7	163	59	37	.	22	.	.	.	288
2.50 - 2.99	.	.	.	.	15	7	7	.	7	7	7	7	57
3.00 - 3.49	.	.	.	.	.	.	.	.	.	.	.	.	0
3.50 - 3.99	.	.	.	.	.	.	7	15	.	.	.	.	22
4.00 - 4.49	.	.	.	.	.	.	.	7	.	.	.	.	7
4.50 - 4.99	.	.	.	.	.	.	.	.	.	.	.	.	0
5.00 - Greater	.	.	.	.	.	.	.	.	.	.	.	.	0
Total	60	178	489	1076	1217	934	2112	1595	1424	192	675	44	

Table B2

Monthly Joint Distribution of H_{mo} versus T_p

January 1990, Gage 630
Percent Occurrence(X100) of Height and Period

Height, m	2.0-2.9	3.0-3.9	4.0-4.9	5.0-5.9	6.0-6.9	7.0-7.9	8.0-8.9	9.0-9.9	10.0-11.9	12.0-13.9	14.0-15.9	16.0-Longer	Total
0.00 - 0.49	.	.	81	.	81	81	163	1057	325	.	81	.	1869
0.50 - 0.99	163	163	163	894	569	569	407	2114	1463	.	.	.	6505
1.00 - 1.49	.	.	.	488	325	244	244	244	81	.	.	.	1626
1.50 - 1.99	.	.	.	.	.	.	.	.	.	.	.	.	0
2.00 - 2.49	.	.	.	.	.	.	.	.	.	.	.	.	0
2.50 - 2.99	.	.	.	.	.	.	.	.	.	.	.	.	0
3.00 - 3.49	.	.	.	.	.	.	.	.	.	.	.	.	0
3.50 - 3.99	.	.	.	.	.	.	.	.	.	.	.	.	0
4.00 - 4.49	.	.	.	.	.	.	.	.	.	.	.	.	0
4.50 - 4.99	.	.	.	.	.	.	.	.	.	.	.	.	0
5.00 - Greater	.	.	.	.	.	.	.	.	.	.	.	.	0
Total	163	163	244	1382	975	894	814	3415	1869	0	81	0	

February 1990, Gage 630
Percent Occurrence(X100) of Height and Period

Height, m	2.0-2.9	3.0-3.9	4.0-4.9	5.0-5.9	6.0-6.9	7.0-7.9	8.0-8.9	9.0-9.9	10.0-11.9	12.0-13.9	14.0-15.9	16.0-Longer	Total
0.00 - 0.49	.	.	.	.	.	.	.	180	270	.	.	.	450
0.50 - 0.99	.	90	180	90	631	901	541	1081	721	.	541	.	4776
1.00 - 1.49	.	.	270	721	811	180	270	270	270	.	270	.	3062
1.50 - 1.99	.	.	.	360	360	.	90	180	90	.	90	.	1170
2.00 - 2.49	.	.	.	.	180	180	.	.	.	.	.	.	360
2.50 - 2.99	.	.	.	.	.	.	90	.	.	.	.	90	180
3.00 - 3.49	.	.	.	.	.	.	.	.	.	.	.	.	0
3.50 - 3.99	.	.	.	.	.	.	.	.	.	.	.	.	0
4.00 - 4.49	.	.	.	.	.	.	.	.	.	.	.	.	0
4.50 - 4.99	.	.	.	.	.	.	.	.	.	.	.	.	0
5.00 - Greater	.	.	.	.	.	.	.	.	.	.	.	.	0
Total	0	90	450	1171	1982	1261	991	1711	1351	0	901	90	

March 1990, Gage 630
Percent Occurrence(X100) of Height and Period

Height, m	2.0-2.9	3.0-3.9	4.0-4.9	5.0-5.9	6.0-6.9	7.0-7.9	8.0-8.9	9.0-9.9	10.0-11.9	12.0-13.9	14.0-15.9	16.0-Longer	Total
0.00 - 0.49	.	.	84	.	.	.	420	.	420	252	840	.	2016
0.50 - 0.99	.	.	.	588	168	504	1008	252	840	.	588	.	3948
1.00 - 1.49	.	.	420	504	168	168	588	84	.	.	168	.	2100
1.50 - 1.99	.	.	.	336	252	.	.	336	168	.	.	.	1092
2.00 - 2.49	.	.	.	.	168	252	336	.	.	.	.	.	756
2.50 - 2.99	.	.	.	.	84	.	.	.	.	.	.	.	84
3.00 - 3.49	.	.	.	.	.	.	.	.	.	.	.	.	0
3.50 - 3.99	.	.	.	.	.	.	.	.	.	.	.	.	0
4.00 - 4.49	.	.	.	.	.	.	.	.	.	.	.	.	0
4.50 - 4.99	.	.	.	.	.	.	.	.	.	.	.	.	0
5.00 - Greater	.	.	.	.	.	.	.	.	.	.	.	.	0
Total	0	0	504	1428	840	924	2352	672	1428	252	1596	0	

(Continued)

(Sheet 1 of 4)

Table B2 (Continued)

April 1990, Gage 630
Percent Occurrence(X100) of Height and Period

Height, m	2.0-2.9	3.0-3.9	4.0-4.9	5.0-5.9	6.0-6.9	7.0-7.9	8.0-8.9	9.0-9.9	10.0-11.9	12.0-13.9	14.0-15.9	16.0-Longer	Total
	Period, sec												
0.00 - 0.49	.	.	.	.	.	.	.	87	.	.	.	.	87
0.50 - 0.99	.	87	174	174	696	522	1391	1652	1478	87	435	.	6696
1.00 - 1.49	.	.	87	87	261	261	696	522	174	87	261	.	2436
1.50 - 1.99	.	.	.	261	174	.	87	.	.	.	.	.	522
2.00 - 2.49	.	.	.	87	174	.	.	.	.	.	.	.	261
2.50 - 2.99	.	.	.	.	.	.	.	.	.	.	.	.	0
3.00 - 3.49	.	.	.	.	.	.	.	.	.	.	.	.	0
3.50 - 3.99	.	.	.	.	.	.	.	.	.	.	.	.	0
4.00 - 4.49	.	.	.	.	.	.	.	.	.	.	.	.	0
4.50 - 4.99	.	.	.	.	.	.	.	.	.	.	.	.	0
5.00 - Greater	.	.	.	.	.	.	.	.	.	.	.	.	0
Total	0	87	261	609	1305	783	2174	2261	1652	174	696	0	

May 1990, Gage 630
Percent Occurrence(X100) of Height and Period

Height, m	2.0-2.9	3.0-3.9	4.0-4.9	5.0-5.9	6.0-6.9	7.0-7.9	8.0-8.9	9.0-9.9	10.0-11.9	12.0-13.9	14.0-15.9	16.0-Longer	Total
	Period, sec												
0.00 - 0.49	.	.	.	.	81	81	.	565	403	.	81	.	1211
0.50 - 0.99	.	323	323	403	484	968	1855	81	806	323	323	.	5889
1.00 - 1.49	.	81	484	403	565	242	242	81	81	81	81	.	2341
1.50 - 1.99	.	.	.	161	.	81	81	.	.	.	.	.	323
2.00 - 2.49	.	.	.	.	81	81	.	.	.	.	.	.	162
2.50 - 2.99	.	.	.	.	81	.	.	.	.	.	.	.	81
3.00 - 3.49	.	.	.	.	.	.	.	.	.	.	.	.	0
3.50 - 3.99	.	.	.	.	.	.	.	.	.	.	.	.	0
4.00 - 4.49	.	.	.	.	.	.	.	.	.	.	.	.	0
4.50 - 4.99	.	.	.	.	.	.	.	.	.	.	.	.	0
5.00 - Greater	.	.	.	.	.	.	.	.	.	.	.	.	0
Total	0	404	807	967	1292	1453	2178	727	1290	404	485	0	

June 1990, Gage 630
Percent Occurrence(X100) of Height and Period

Height, m	2.0-2.9	3.0-3.9	4.0-4.9	5.0-5.9	6.0-6.9	7.0-7.9	8.0-8.9	9.0-9.9	10.0-11.9	12.0-13.9	14.0-15.9	16.0-Longer	Total
	Period, sec												
0.00 - 0.49	.	.	.	.	215	215	860	108	.	108	.	.	1506
0.50 - 0.99	108	108	323	215	968	430	2581	1183	.	.	108	.	6024
1.00 - 1.49	.	108	108	538	.	.	323	215	.	.	.	.	1292
1.50 - 1.99	.	.	.	.	108	.	215	108	108	.	538	.	1077
2.00 - 2.49	.	.	.	.	108	.	.	.	.	.	.	.	108
2.50 - 2.99	.	.	.	.	.	.	.	.	.	.	.	.	0
3.00 - 3.49	.	.	.	.	.	.	.	.	.	.	.	.	0
3.50 - 3.99	.	.	.	.	.	.	.	.	.	.	.	.	0
4.00 - 4.49	.	.	.	.	.	.	.	.	.	.	.	.	0
4.50 - 4.99	.	.	.	.	.	.	.	.	.	.	.	.	0
5.00 - Greater	.	.	.	.	.	.	.	.	.	.	.	.	0
Total	108	216	431	753	1399	645	3979	1614	108	108	646	0	

(Continued)

(Sheet 2 of 4)

Table B2 (Continued)

July 1990, Gage 630
Percent Occurrence(X100) of Height and Period

Height, m	2.0-2.9	3.0-3.9	4.0-4.9	5.0-5.9	6.0-6.9	7.0-7.9	8.0-8.9	9.0-9.9	10.0-11.9	12.0-13.9	14.0-15.9	16.0-Longer	Total
	Period, sec												
0.00 - 0.49	.	.	.	.	93	467	467	374	93	.	.	.	1494
0.50 - 0.99	.	187	467	654	935	1028	1308	748	187	.	.	.	5514
1.00 - 1.49	.	.	280	561	.	187	841	93	280	.	.	.	2242
1.50 - 1.99	.	.	.	93	.	.	.	187	467	.	.	.	747
2.00 - 2.49	.	.	.	.	.	.	.	.	.	.	.	.	0
2.50 - 2.99	.	.	.	.	.	.	.	.	.	.	.	.	0
3.00 - 3.49	.	.	.	.	.	.	.	.	.	.	.	.	0
3.50 - 3.99	.	.	.	.	.	.	.	.	.	.	.	.	0
4.00 - 4.49	.	.	.	.	.	.	.	.	.	.	.	.	0
4.50 - 4.99	.	.	.	.	.	.	.	.	.	.	.	.	0
5.00 - Greater	.	.	.	.	.	.	.	.	.	.	.	.	0
Total	0	187	747	1308	1028	1682	2616	1402	1027	0	0	0	

August 1990, Gage 630
Percent Occurrence(X100) of Height and Period

Height, m	2.0-2.9	3.0-3.9	4.0-4.9	5.0-5.9	6.0-6.9	7.0-7.9	8.0-8.9	9.0-9.9	10.0-11.9	12.0-13.9	14.0-15.9	16.0-Longer	Total
	Period, sec												
0.00 - 0.49	.	.	.	84	84	252	1681	924	336	84	84	.	3529
0.50 - 0.99	168	.	.	252	168	.	1092	924	924	.	504	420	4452
1.00 - 1.49	.	.	.	.	84	84	756	336	336	.	252	.	1848
1.50 - 1.99	.	.	.	.	.	.	84	.	.	.	84	.	168
2.00 - 2.49	.	.	.	.	.	.	.	.	.	.	.	.	0
2.50 - 2.99	.	.	.	.	.	.	.	.	.	.	.	.	0
3.00 - 3.49	.	.	.	.	.	.	.	.	.	.	.	.	0
3.50 - 3.99	.	.	.	.	.	.	.	.	.	.	.	.	0
4.00 - 4.49	.	.	.	.	.	.	.	.	.	.	.	.	0
4.50 - 4.99	.	.	.	.	.	.	.	.	.	.	.	.	0
5.00 - Greater	.	.	.	.	.	.	.	.	.	.	.	.	0
Total	168	0	0	336	336	336	3613	2184	1596	84	924	420	

September 1990, Gage 630
Percent Occurrence(X100) of Height and Period

Height, m	2.0-2.9	3.0-3.9	4.0-4.9	5.0-5.9	6.0-6.9	7.0-7.9	8.0-8.9	9.0-9.9	10.0-11.9	12.0-13.9	14.0-15.9	16.0-Longer	Total
	Period, sec												
0.00 - 0.49	.	.	.	83	.	.	333	.	.	.	83	.	499
0.50 - 0.99	.	667	333	417	167	250	1583	667	1000	417	917	.	6418
1.00 - 1.49	.	.	167	750	83	.	333	250	417	167	333	.	2500
1.50 - 1.99	.	.	.	167	250	.	83	83	.	.	.	.	583
2.00 - 2.49	.	.	.	.	.	.	.	.	.	.	.	.	0
2.50 - 2.99	.	.	.	.	.	.	.	.	.	.	.	.	0
3.00 - 3.49	.	.	.	.	.	.	.	.	.	.	.	.	0
3.50 - 3.99	.	.	.	.	.	.	.	.	.	.	.	.	0
4.00 - 4.49	.	.	.	.	.	.	.	.	.	.	.	.	0
4.50 - 4.99	.	.	.	.	.	.	.	.	.	.	.	.	0
5.00 - Greater	.	.	.	.	.	.	.	.	.	.	.	.	0
Total	0	667	500	1417	500	250	2332	1000	1417	584	1333	0	

(Continued)

(Sheet 3 of 4)

Table B2 (Concluded)

October 1990, Gage 630
Percent Occurrence(X100) of Height and Period

Height, m	2.0-2.9	3.0-3.9	4.0-4.9	5.0-5.9	6.0-6.9	7.0-7.9	8.0-8.9	9.0-9.9	10.0-11.9	12.0-13.9	14.0-15.9	16.0-Longer	Total
	Period, sec												
0.00 - 0.49	.	.	.	.	.	.	.	.	.	.	.	.	0
0.50 - 0.99	.	171	513	256	85	171	769	855	940	.	513	.	4273
1.00 - 1.49	.	.	256	513	427	171	598	855	684	85	85	.	3674
1.50 - 1.99	.	.	.	427	342	256	.	.	85	.	.	.	1110
2.00 - 2.49	.	.	.	.	171	.	.	.	256	.	.	.	427
2.50 - 2.99	.	.	.	.	.	.	.	.	85	85	85	.	255
3.00 - 3.49	.	.	.	.	.	.	.	.	.	.	.	.	0
3.50 - 3.99	.	.	.	.	.	.	85	85	.	.	.	.	170
4.00 - 4.49	.	.	.	.	.	.	.	85	.	.	.	.	85
4.50 - 4.99	.	.	.	.	.	.	.	.	.	.	.	.	0
5.00 - Greater	.	.	.	.	.	.	.	.	.	.	.	.	0
Total	0	171	769	1196	1025	598	1452	1880	2050	170	683	0	

November 1990, Gage 630
Percent Occurrence(X100) of Height and Period

Height, m	2.0-2.9	3.0-3.9	4.0-4.9	5.0-5.9	6.0-6.9	7.0-7.9	8.0-8.9	9.0-9.9	10.0-11.9	12.0-13.9	14.0-15.9	16.0-Longer	Total
	Period, sec												
0.00 - 0.49	253	.	.	.	.	253	886	127	127	127	127	.	1900
0.50 - 0.99	127	.	127	380	759	253	380	380	1013	.	.	.	3419
1.00 - 1.49	.	.	253	253	380	253	633	253	253	.	.	.	2278
1.50 - 1.99	.	.	.	253	506	253	127	127	127	.	.	.	1393
2.00 - 2.49	.	.	.	.	633	127	.	.	.	.	.	.	760
2.50 - 2.99	.	.	.	.	.	127	.	.	.	.	.	.	127
3.00 - 3.49	.	.	.	.	.	.	.	.	.	.	.	.	0
3.50 - 3.99	.	.	.	.	.	.	.	127	.	.	.	.	127
4.00 - 4.49	.	.	.	.	.	.	.	.	.	.	.	.	0
4.50 - 4.99	.	.	.	.	.	.	.	.	.	.	.	.	0
5.00 - Greater	.	.	.	.	.	.	.	.	.	.	.	.	0
Total	380	0	380	886	2278	1266	2026	1014	1520	127	127	0	

December 1990, Gage 630
Percent Occurrence(X100) of Height and Period

Height, m	2.0-2.9	3.0-3.9	4.0-4.9	5.0-5.9	6.0-6.9	7.0-7.9	8.0-8.9	9.0-9.9	10.0-11.9	12.0-13.9	14.0-15.9	16.0-Longer	Total
	Period, sec												
0.00 - 0.49	.	.	.	.	.	.	.	165	83	83	165	.	496
0.50 - 0.99	.	83	248	413	579	248	413	413	496	248	165	.	3306
1.00 - 1.49	.	.	413	496	579	331	331	248	909	.	83	.	3390
1.50 - 1.99	.	.	83	413	331	579	413	248	.	.	.	.	2067
2.00 - 2.49	.	.	.	.	579	83	83	.	.	.	.	.	745
2.50 - 2.99	.	.	.	.	.	.	.	.	.	.	.	.	0
3.00 - 3.49	.	.	.	.	.	.	.	.	.	.	.	.	0
3.50 - 3.99	.	.	.	.	.	.	.	.	.	.	.	.	0
4.00 - 4.49	.	.	.	.	.	.	.	.	.	.	.	.	0
4.50 - 4.99	.	.	.	.	.	.	.	.	.	.	.	.	0
5.00 - Greater	.	.	.	.	.	.	.	.	.	.	.	.	0
Total	0	83	744	1322	2068	1241	1240	1074	1488	331	413	0	

(Sheet 4 of 4)

Table B3

Annual Joint Distribution of H_{mo} versus T_p (All Years)

Annual 1980-1990, Gage 630
Percent Occurrence(X100) of Height and Period

	Period, sec												
Height, m	2.0-2.9	3.0-3.9	4.0-4.9	5.0-5.9	6.0-6.9	7.0-7.9	8.0-8.9	9.0-9.9	10.0-11.9	12.0-13.9	14.0-15.9	16.0-Longer	Total
0.00 - 0.49	29	14	27	61	89	116	333	281	191	69	126	3	1339
0.50 - 0.99	39	137	253	501	586	522	874	736	787	143	230	17	4825
1.00 - 1.49	.	9	148	403	437	256	263	211	335	41	124	4	2231
1.50 - 1.99	.	.	12	163	246	111	82	79	128	33	76	4	934
2.00 - 2.49	.	.	1	24	93	69	55	38	61	29	39	1	410
2.50 - 2.99	.	.	.	1	9	31	17	14	34	10	24	1	141
3.00 - 3.49	.	.	.	.	1	11	13	12	15	4	8	.	64
3.50 - 3.99	.	.	.	.	.	1	6	7	11	4	4	.	33
4.00 - 4.49	.	.	.	.	.	.	1	4	7	1	4	.	17
4.50 - 4.99	.	.	.	.	.	.	.	1	2	.	.	.	3
5.00 - Greater	.	.	.	.	.	.	1	.	1	1	1	.	4
Total	68	160	441	1153	1461	1117	1645	1383	1572	335	636	30	

Table B4

Monthly Joint Distribution of H_{mo} versus T_p (All Years)

January 1980-1990, Gage 630
Percent Occurrence(X100) of Height and Period

Height, m	Period, sec 2.0-2.9	3.0-3.9	4.0-4.9	5.0-5.9	6.0-6.9	7.0-7.9	8.0-8.9	9.0-9.9	10.0-11.9	12.0-13.9	14.0-15.9	16.0-Longer	Total
0.00 - 0.49	92	8	8	84	75	42	159	260	226	50	92	.	1096
0.50 - 0.99	75	218	243	410	410	360	352	678	871	109	226	.	3952
1.00 - 1.49	.	17	168	536	536	260	193	201	486	25	59	8	2489
1.50 - 1.99	.	.	25	318	410	193	101	92	218	25	50	.	1432
2.00 - 2.49	.	.	.	25	184	176	101	25	101	34	25	8	679
2.50 - 2.99	.	.	.	.	17	67	42	17	67	17	42	.	269
3.00 - 3.49	.	.	.	.	.	8	25	8	25	.	.	.	66
3.50 - 3.99	.	.	.	.	.	.	.	.	.	.	.	.	0
4.00 - 4.49	.	.	.	.	.	.	.	.	8	.	.	.	8
4.50 - 4.99	.	.	.	.	.	.	.	.	8	.	.	.	8
5.00 - Greater	.	.	.	.	.	.	.	.	.	.	.	.	0
Total	167	243	444	1373	1632	1106	973	1281	2010	260	494	16	

February 1980-1990, Gage 630
Percent Occurrence(X100) of Height and Period

Height, m	Period, sec 2.0-2.9	3.0-3.9	4.0-4.9	5.0-5.9	6.0-6.9	7.0-7.9	8.0-8.9	9.0-9.9	10.0-11.9	12.0-13.9	14.0-15.9	16.0-Longer	Total
0.00 - 0.49	9	.	9	45	62	45	89	62	80	27	107	.	535
0.50 - 0.99	54	89	178	428	482	312	500	687	1017	18	169	9	3943
1.00 - 1.49	.	9	134	642	633	232	303	339	544	71	205	.	3112
1.50 - 1.99	.	.	9	214	357	178	107	107	196	54	98	.	1320
2.00 - 2.49	.	.	.	80	152	45	36	71	80	45	98	.	607
2.50 - 2.99	.	.	.	9	9	45	18	9	98	18	62	9	277
3.00 - 3.49	.	.	.	.	.	18	9	27	27	18	18	.	117
3.50 - 3.99	.	.	.	.	.	.	.	9	9	.	9	.	27
4.00 - 4.49	.	.	.	.	.	.	.	9	36	.	9	.	54
4.50 - 4.99	.	.	.	.	.	.	.	.	.	.	.	.	0
5.00 - Greater	.	.	.	.	.	.	9	.	.	.	.	.	9
Total	63	98	330	1418	1695	875	1071	1320	2087	251	775	18	

March 1980-1990, Gage 630
Percent Occurrence(X100) of Height and Period

Height, m	Period, sec 2.0-2.9	3.0-3.9	4.0-4.9	5.0-5.9	6.0-6.9	7.0-7.9	8.0-8.9	9.0-9.9	10.0-11.9	12.0-13.9	14.0-15.9	16.0-Longer	Total
0.00 - 0.49	8	.	8	16	40	40	113	32	137	73	129	.	596
0.50 - 0.99	8	73	185	468	444	427	645	702	815	121	202	.	4090
1.00 - 1.49	.	8	218	411	492	347	323	266	621	48	290	.	3024
1.50 - 1.99	.	.	8	242	258	105	81	145	234	73	113	.	1259
2.00 - 2.49	.	.	.	16	73	48	113	56	137	32	97	.	572
2.50 - 2.99	.	.	.	.	24	16	24	8	48	16	40	.	176
3.00 - 3.49	.	.	.	.	8	16	8	16	48	8	8	.	112
3.50 - 3.99	.	.	.	.	.	.	.	16	56	.	16	.	88
4.00 - 4.49	.	.	.	.	.	.	8	16	16	.	24	.	64
4.50 - 4.99	.	.	.	.	.	.	.	.	16	.	.	.	16
5.00 - Greater	.	.	.	.	.	.	.	.	.	.	.	.	0
Total	16	81	419	1153	1339	999	1315	1257	2128	371	919	0	

(Continued)

(Sheet 1 of 4)

Table B4 (Continued)

April 1980-1990, Gage 630
Percent Occurrence(X100) of Height and Period

Height, m	2.0-2.9	3.0-3.9	4.0-4.9	5.0-5.9	6.0-6.9	7.0-7.9	8.0-8.9	9.0-9.9	10.0-11.9	12.0-13.9	14.0-15.9	16.0-Longer	Total
	Period, sec												
0.00 - 0.49	8	8	17	50	33	25	265	199	166	83	83	.	937
0.50 - 0.99	75	174	257	406	539	481	746	870	1069	240	398	.	5255
1.00 - 1.49	.	8	116	215	414	340	356	340	323	58	157	.	2327
1.50 - 1.99	.	.	.	157	141	91	99	108	182	25	91	.	894
2.00 - 2.49	.	.	.	41	58	8	50	58	50	25	8	.	298
2.50 - 2.99	.	.	.	.	8	17	25	17	33	25	17	.	142
3.00 - 3.49	.	.	.	.	.	25	17	25	25	.	.	.	92
3.50 - 3.99	.	.	.	.	.	8	33	.	.	.	.	.	41
4.00 - 4.49	.	.	.	.	.	.	8	.	.	.	.	.	8
4.50 - 4.99	.	.	.	.	.	.	.	8	.	.	.	.	8
5.00 - Greater	.	.	.	.	.	.	.	.	.	.	.	.	0
Total	83	190	390	869	1193	995	1599	1625	1848	456	754	0	

May 1980-1990, Gage 630
Percent Occurrence(X100) of Height and Period

Height, m	2.0-2.9	3.0-3.9	4.0-4.9	5.0-5.9	6.0-6.9	7.0-7.9	8.0-8.9	9.0-9.9	10.0-11.9	12.0-13.9	14.0-15.9	16.0-Longer	Total
	Period, sec												
0.00 - 0.49	8	16	41	73	138	155	423	269	171	41	73	.	1408
0.50 - 0.99	16	187	334	602	578	822	1302	936	716	106	212	.	5811
1.00 - 1.49	.	8	130	252	342	220	391	228	293	16	81	.	1961
1.50 - 1.99	.	.	8	57	81	41	114	65	98	24	57	.	545
2.00 - 2.49	.	.	.	16	24	57	.	33	8	24	24	.	186
2.50 - 2.99	.	.	.	.	16	8	8	8	8	16	8	.	72
3.00 - 3.49	.	.	.	.	.	.	.	.	.	8	8	.	16
3.50 - 3.99	.	.	.	.	.	.	.	.	.	.	.	.	0
4.00 - 4.49	.	.	.	.	.	.	.	.	.	.	.	.	0
4.50 - 4.99	.	.	.	.	.	.	.	.	.	.	.	.	0
5.00 - Greater	.	.	.	.	.	.	.	.	.	.	.	.	0
Total	24	211	513	1000	1179	1303	2238	1539	1294	235	463	0	

June 1980-1990, Gage 630
Percent Occurrence(X100) of Height and Period

Height, m	2.0-2.9	3.0-3.9	4.0-4.9	5.0-5.9	6.0-6.9	7.0-7.9	8.0-8.9	9.0-9.9	10.0-11.9	12.0-13.9	14.0-15.9	16.0-Longer	Total
	Period, sec												
0.00 - 0.49	26	35	53	132	220	369	738	545	202	44	35	.	2399
0.50 - 0.99	53	237	369	659	729	703	1696	949	483	141	44	.	6063
1.00 - 1.49	.	9	88	228	185	158	185	105	88	.	44	.	1090
1.50 - 1.99	.	.	18	44	70	53	35	18	70	.	53	.	361
2.00 - 2.49	.	.	.	.	26	18	35	9	.	.	.	.	88
2.50 - 2.99	.	.	.	.	.	.	.	.	.	.	.	.	0
3.00 - 3.49	.	.	.	.	.	.	.	.	.	.	.	.	0
3.50 - 3.99	.	.	.	.	.	.	.	.	.	.	.	.	0
4.00 - 4.49	.	.	.	.	.	.	.	.	.	.	.	.	0
4.50 - 4.99	.	.	.	.	.	.	.	.	.	.	.	.	0
5.00 - Greater	.	.	.	.	.	.	.	.	.	.	.	.	0
Total	79	281	528	1063	1230	1301	2689	1626	843	185	176	0	

(Continued)

(Sheet 2 of 4)

Table B4 (Continued)

July 1980-1990, Gage 630
Percent Occurrence(X100) of Height and Period

Height, m	Period, sec 2.0-2.9	3.0-3.9	4.0-4.9	5.0-5.9	6.0-6.9	7.0-7.9	8.0-8.9	9.0-9.9	10.0-11.9	12.0-13.9	14.0-15.9	16.0-Longer	Total
0.00 - 0.49	9	17	52	95	206	318	988	713	275	103	206	17	2999
0.50 - 0.99	34	137	309	644	902	816	1452	885	395	223	120	69	5986
1.00 - 1.49	.	17	69	206	241	86	120	43	43	.	.	.	825
1.50 - 1.99	.	.	.	52	9	17	26	17	43	.	.	.	164
2.00 - 2.49	.	.	.	9	.	.	9	.	.	.	.	.	18
2.50 - 2.99	.	.	.	.	.	.	.	.	.	.	.	.	0
3.00 - 3.49	.	.	.	.	.	.	.	.	.	.	.	.	0
3.50 - 3.99	.	.	.	.	.	.	.	.	.	.	.	.	0
4.00 - 4.49	.	.	.	.	.	.	.	.	.	.	.	.	0
4.50 - 4.99	.	.	.	.	.	.	.	.	.	.	.	.	0
5.00 - Greater	.	.	.	.	.	.	.	.	.	.	.	.	0
Total	43	171	430	1006	1358	1237	2595	1658	756	326	326	86	

August 1980-1990, Gage 630
Percent Occurrence(X100) of Height and Period

Height, m	Period, sec 2.0-2.9	3.0-3.9	4.0-4.9	5.0-5.9	6.0-6.9	7.0-7.9	8.0-8.9	9.0-9.9	10.0-11.9	12.0-13.9	14.0-15.9	16.0-Longer	Total
0.00 - 0.49	25	25	59	119	153	195	593	500	356	68	93	.	2186
0.50 - 0.99	42	85	203	576	831	746	1356	839	653	153	331	42	5857
1.00 - 1.49	.	8	136	331	271	195	203	119	93	17	34	.	1407
1.50 - 1.99	.	.	.	68	136	59	34	17	17	.	34	.	365
2.00 - 2.49	.	.	.	17	25	8	17	.	34	.	8	.	109
2.50 - 2.99	.	.	.	.	8	.	17	.	8	.	8	.	41
3.00 - 3.49	.	.	.	.	.	8	8	.	8	.	.	.	24
3.50 - 3.99	.	.	.	.	.	.	.	8	.	.	.	.	8
4.00 - 4.49	.	.	.	.	.	.	.	.	.	.	.	.	0
4.50 - 4.99	.	.	.	.	.	.	.	.	.	.	.	.	0
5.00 - Greater	.	.	.	.	.	.	.	.	.	.	.	.	0
Total	67	118	398	1111	1424	1211	2228	1483	1169	238	508	42	

September 1980-1990, Gage 630
Percent Occurrence(X100) of Height and Period

Height, m	Period, sec 2.0-2.9	3.0-3.9	4.0-4.9	5.0-5.9	6.0-6.9	7.0-7.9	8.0-8.9	9.0-9.9	10.0-11.9	12.0-13.9	14.0-15.9	16.0-Longer	Total
0.00 - 0.49	8	8	8	34	25	17	118	269	218	101	92	8	906
0.50 - 0.99	.	118	185	403	546	537	865	739	1024	160	302	.	4879
1.00 - 1.49	.	8	92	445	495	311	403	210	344	101	176	8	2593
1.50 - 1.99	.	.	8	143	285	126	92	118	67	25	118	8	990
2.00 - 2.49	.	.	.	34	76	50	76	25	67	67	67	.	462
2.50 - 2.99	.	.	.	.	.	42	25	8	.	8	8	.	91
3.00 - 3.49	.	.	.	.	.	8	.	8	8	8	8	.	40
3.50 - 3.99	.	.	.	.	.	.	.	.	8	8	8	.	24
4.00 - 4.49	.	.	.	.	.	.	.	.	.	.	.	.	0
4.50 - 4.99	.	.	.	.	.	.	.	.	.	.	.	.	0
5.00 - Greater	.	.	.	.	.	.	.	.	.	8	.	.	8
Total	8	134	293	1059	1427	1091	1579	1377	1736	486	779	24	

(Continued)

(Sheet 3 of 4)

Table B4 (Concluded)

October 1980-1990, Gage 630
Percent Occurrence(X100) of Height and Period

Height, m	2.0-2.9	3.0-3.9	4.0-4.9	5.0-5.9	6.0-6.9	7.0-7.9	8.0-8.9	9.0-9.9	10.0-11.9	12.0-13.9	14.0-15.9	16.0-Longer	Total
	Period, sec												
0.00 - 0.49	32	.	.	.	48	65	178	137	218	32	121	.	831
0.50 - 0.99	32	65	169	363	387	331	646	492	936	145	315	8	3889
1.00 - 1.49	.	.	178	613	355	210	169	291	452	81	202	.	2551
1.50 - 1.99	.	.	32	234	387	121	81	105	178	105	202	32	1477
2.00 - 2.49	.	.	.	16	121	169	65	89	153	48	73	8	742
2.50 - 2.99	.	.	.	.	16	105	32	65	48	16	65	.	347
3.00 - 3.49	.	.	.	.	.	32	8	.	16	.	32	.	88
3.50 - 3.99	.	.	.	.	.	.	8	24	.	16	.	.	48
4.00 - 4.49	.	.	.	.	.	.	.	8	16	.	.	.	24
4.50 - 4.99	.	.	.	.	.	.	.	.	.	.	.	.	0
5.00 - Greater	.	.	.	.	.	.	.	.	.	.	.	.	0
Total	64	65	379	1226	1314	1033	1187	1211	2017	443	1010	48	

November 1980-1990, Gage 630
Percent Occurrence(X100) of Height and Period

Height, m	2.0-2.9	3.0-3.9	4.0-4.9	5.0-5.9	6.0-6.9	7.0-7.9	8.0-8.9	9.0-9.9	10.0-11.9	12.0-13.9	14.0-15.9	16.0-Longer	Total
	Period, sec												
0.00 - 0.49	48	29	29	19	48	116	222	174	96	68	212	.	1061
0.50 - 0.99	48	96	376	579	579	453	453	550	627	125	135	48	4069
1.00 - 1.49	.	19	280	511	704	415	289	251	289	39	87	29	2913
1.50 - 1.99	.	.	19	212	347	222	125	77	116	48	10	10	1186
2.00 - 2.49	.	.	.	29	116	125	125	39	19	19	10	.	482
2.50 - 2.99	.	.	.	.	.	29	10	19	48	.	10	.	116
3.00 - 3.49	.	.	.	.	.	.	19	48	.	10	10	.	87
3.50 - 3.99	.	.	.	.	.	.	.	10	39	19	10	.	78
4.00 - 4.49	.	.	.	.	.	.	.	.	.	10	.	.	10
4.50 - 4.99	.	.	.	.	.	.	.	.	.	.	.	.	0
5.00 - Greater	.	.	.	.	.	.	.	.	.	.	.	.	0
Total	96	144	704	1350	1794	1360	1243	1168	1234	338	484	87	

December 1980-1990, Gage 630
Percent Occurrence(X100) of Height and Period

Height, m	2.0-2.9	3.0-3.9	4.0-4.9	5.0-5.9	6.0-6.9	7.0-7.9	8.0-8.9	9.0-9.9	10.0-11.9	12.0-13.9	14.0-15.9	16.0-Longer	Total
	Period, sec												
0.00 - 0.49	75	28	47	66	19	19	112	225	131	141	291	9	1163
0.50 - 0.99	28	169	244	497	637	244	412	469	797	178	281	37	3993
1.00 - 1.49	.	.	187	459	628	309	206	131	422	37	131	.	2510
1.50 - 1.99	.	.	19	225	506	150	94	66	103	9	66	.	1238
2.00 - 2.49	.	.	19	.	281	122	37	47	75	47	56	.	684
2.50 - 2.99	.	.	.	.	.	37	.	19	56	.	28	.	140
3.00 - 3.49	.	.	.	.	.	9	66	19	19	.	9	.	122
3.50 - 3.99	.	.	.	.	.	.	28	19	28	.	9	.	84
4.00 - 4.49	.	.	.	.	.	.	.	9	9	9	9	.	36
4.50 - 4.99	.	.	.	.	.	.	.	.	.	.	.	.	0
5.00 - Greater	.	.	.	.	.	.	.	.	9	9	9	.	27
Total	103	197	516	1247	2071	890	955	1004	1649	430	889	46	

(Sheet 4 of 4)

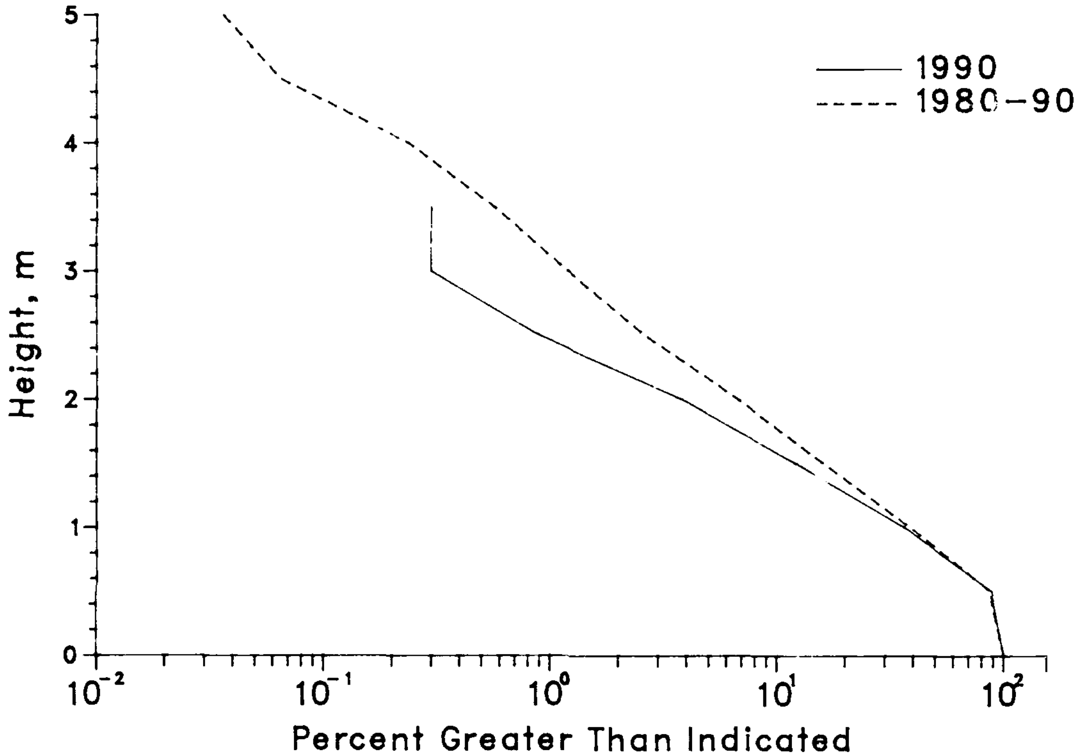


Figure B2. Annual cumulative wave height distributions for Gage 630

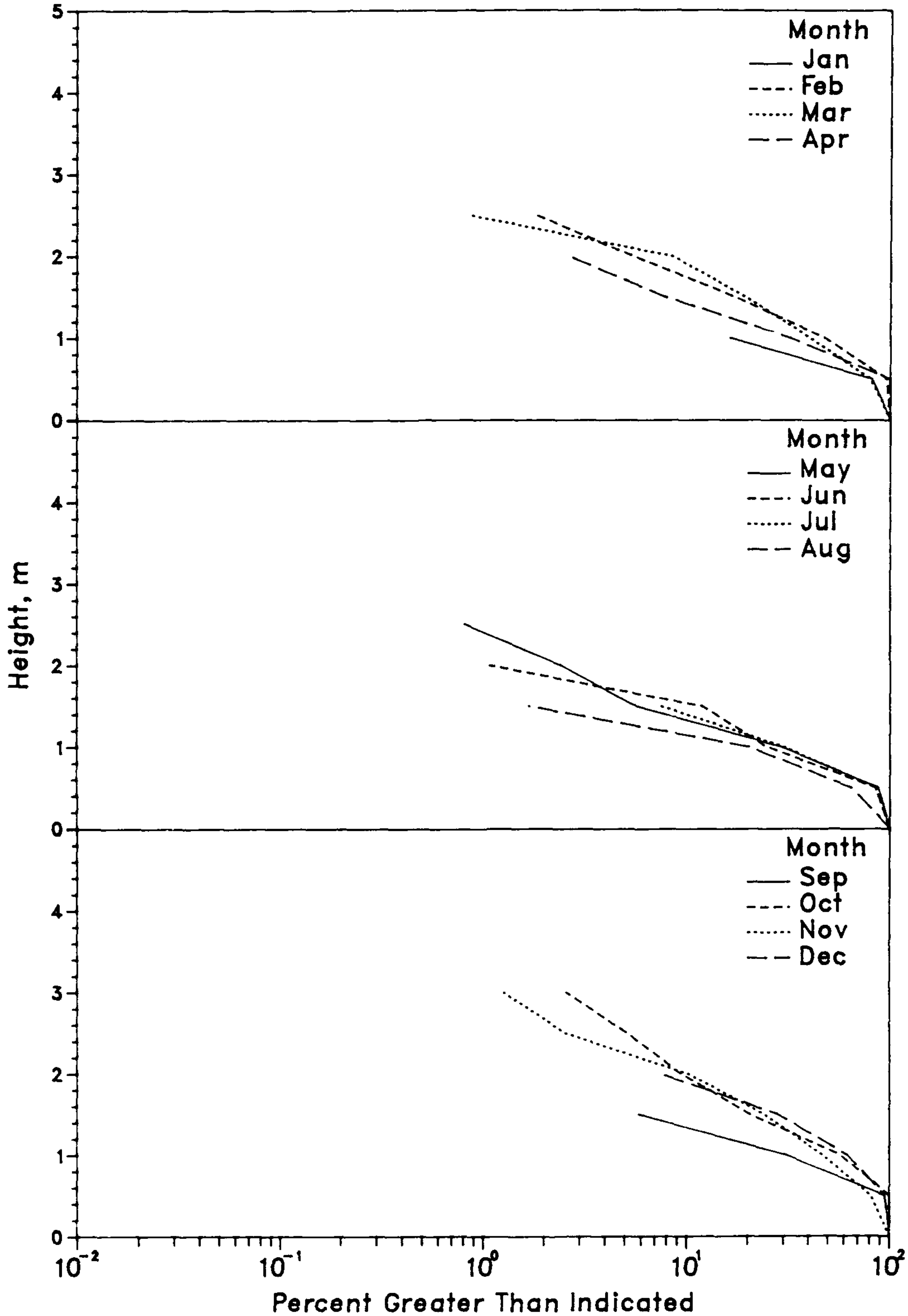


Figure B3. 1990 monthly wave height distributions for Gage 630

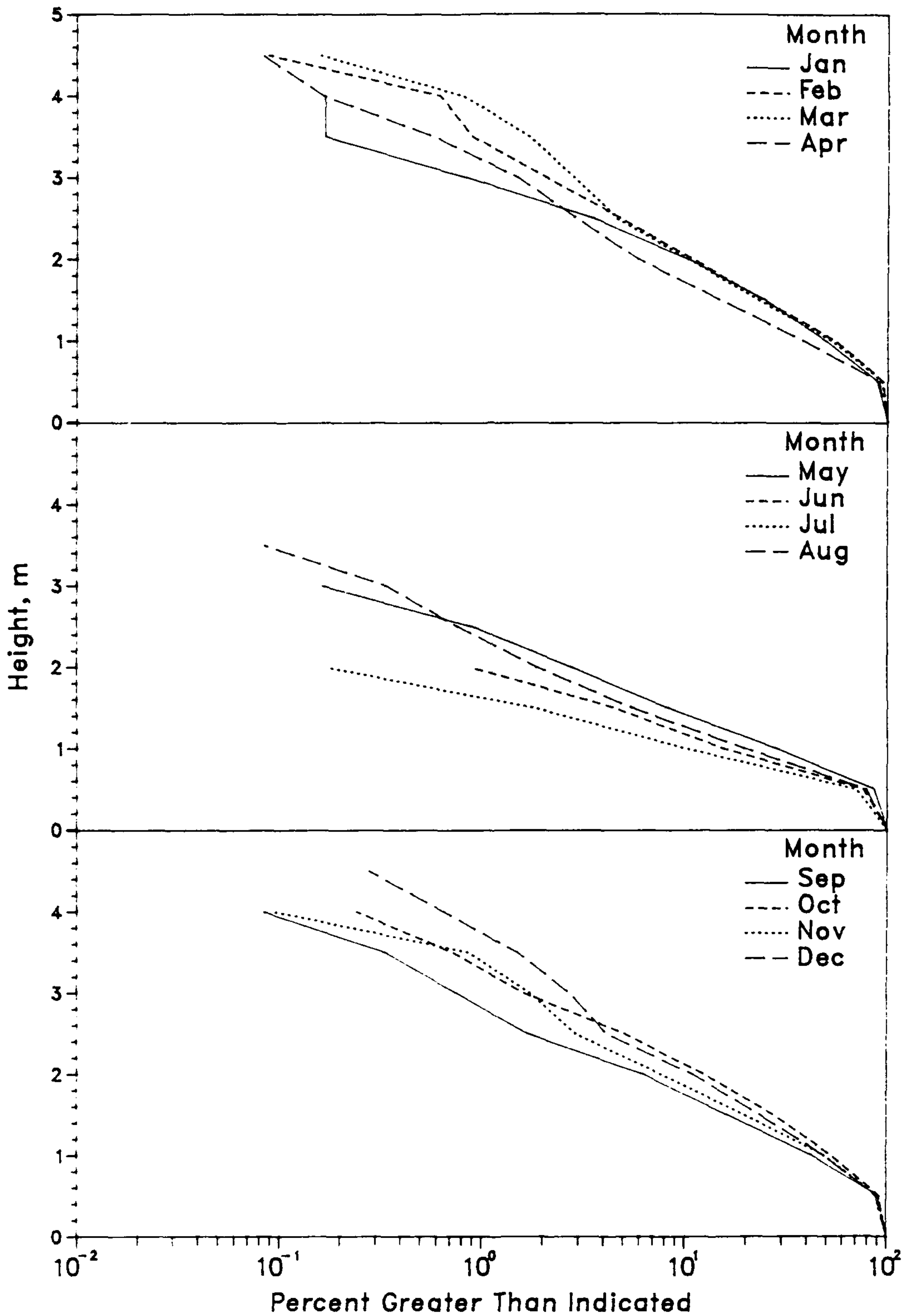


Figure B4. 1980-1990 monthly wave height distributions for Gage 630

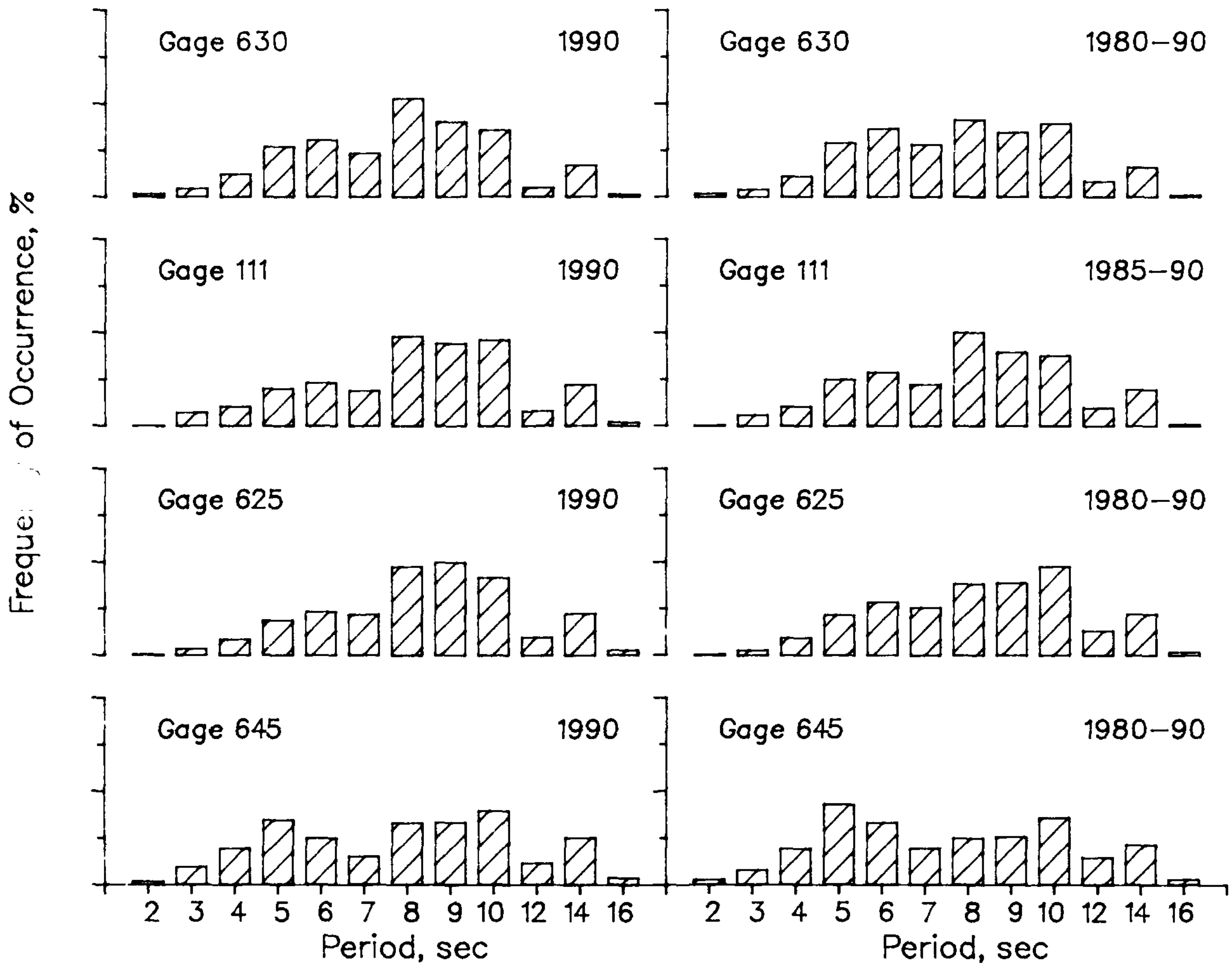


Figure B5. Annual wave period distributions for all gages

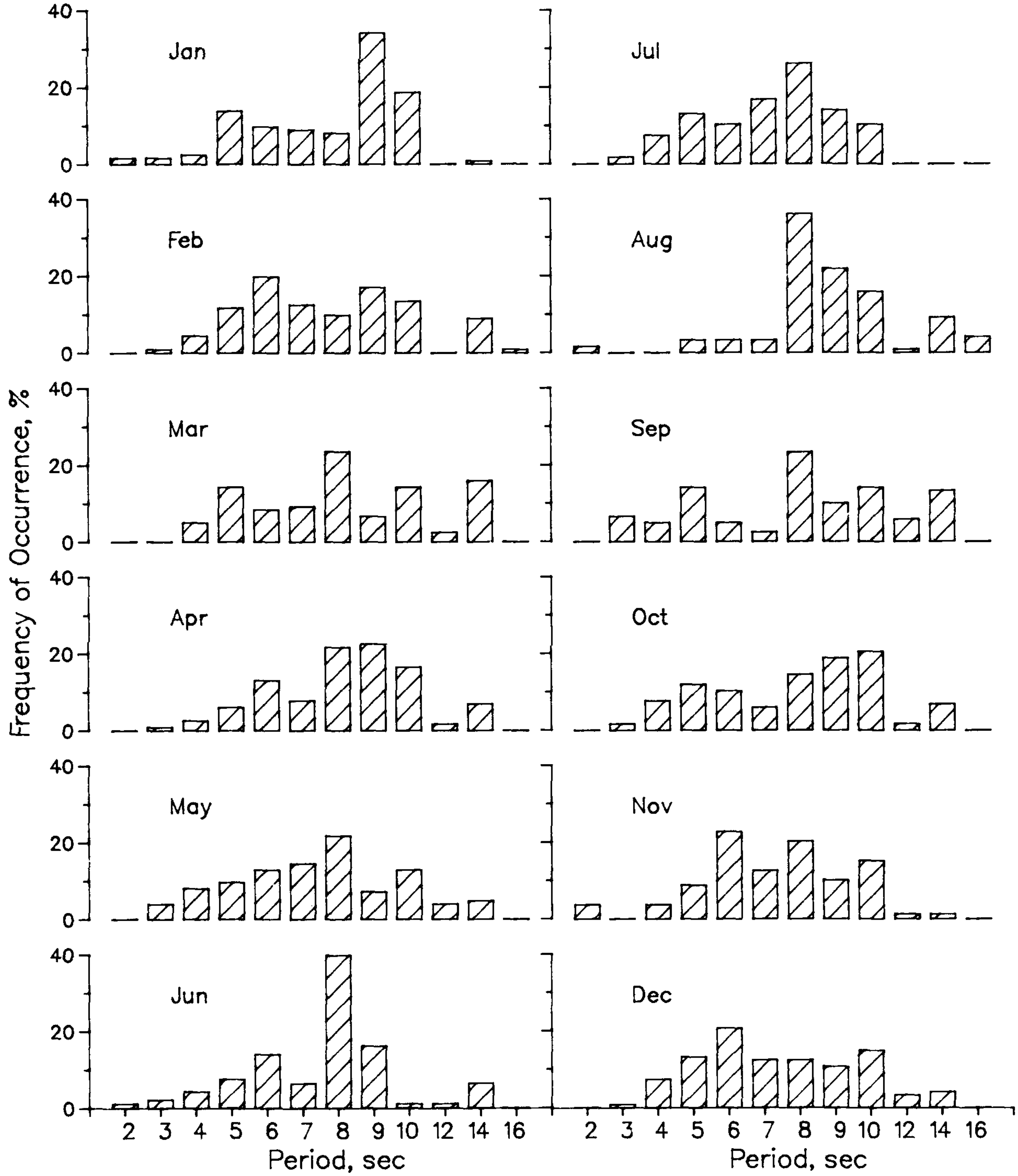


Figure B6. 1990 monthly wave period distributions for Gage 630

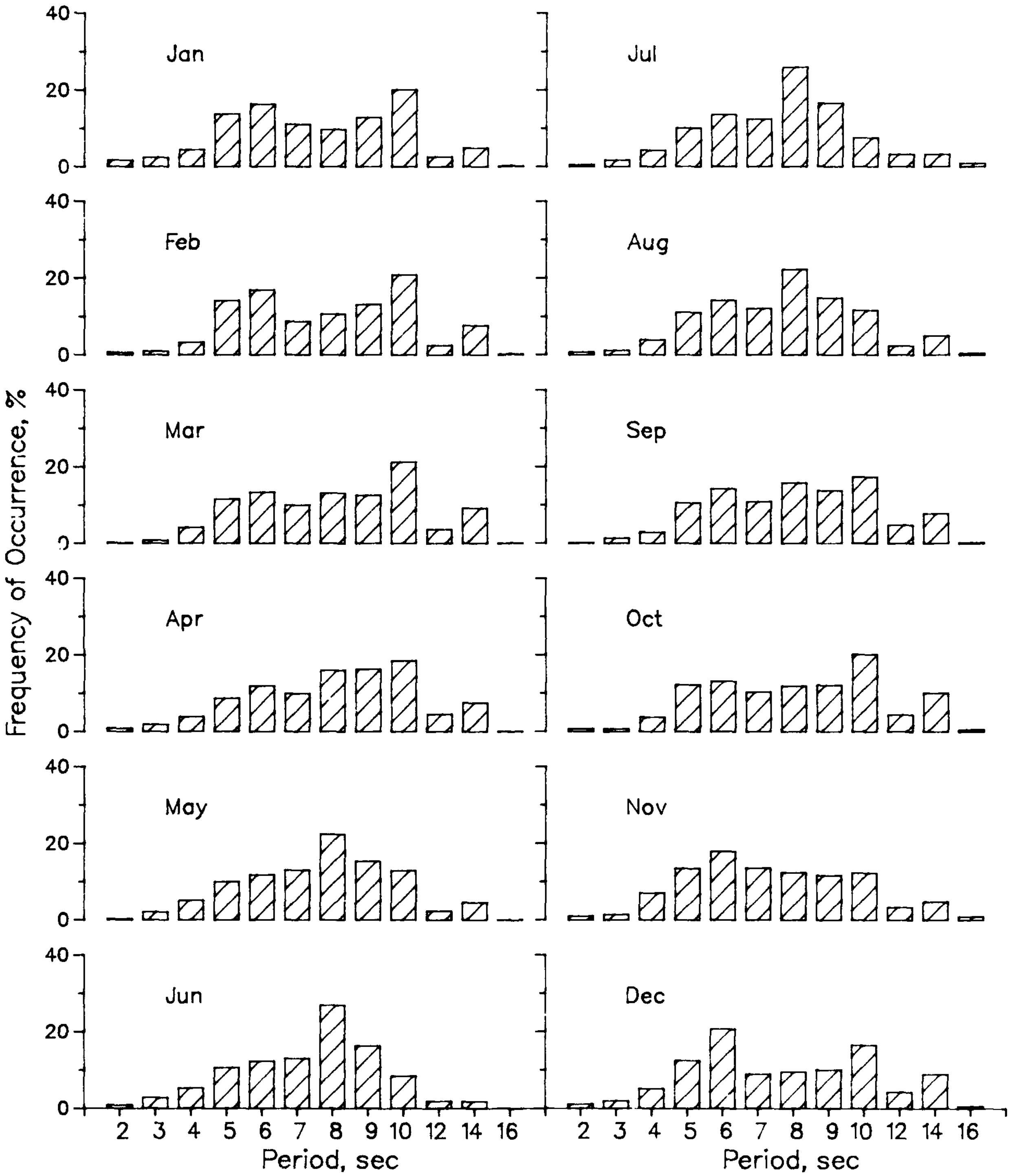


Figure B7. 1980-1990 monthly wave period distributions for Gage 630

Table B5

1990 Persistence of H_{mo} for Gage 630

Height (m)	Consecutive Day(s) or Longer																		
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19+
0.5		17	16			15					12	9		8					6
1.0	53	43	23	15	13	9	7	6	4		3		2						1
1.5	42	25	7	2															
2.0	21	8	2																
2.5	8	1																	
3.0	2																		
3.5	2																		
4.0	1																		

Table B6

1980 through 1990 Persistence of H_{mo} for Gage 630

Height (m)	Consecutive Day(s) or Longer																		
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19+
0.5	20	18	16	15		14	12		11	10		9	8	7	6	5			4
1.0	50	34	24	17	14	10	8	5	4	3		2					1		
1.5	39	22	11	6	4	2			1										
2.0	22	11	4	2		1													
2.5	10	5	2	1															
3.0	5	2	1																
3.5	3	1																	
4.0	1																		

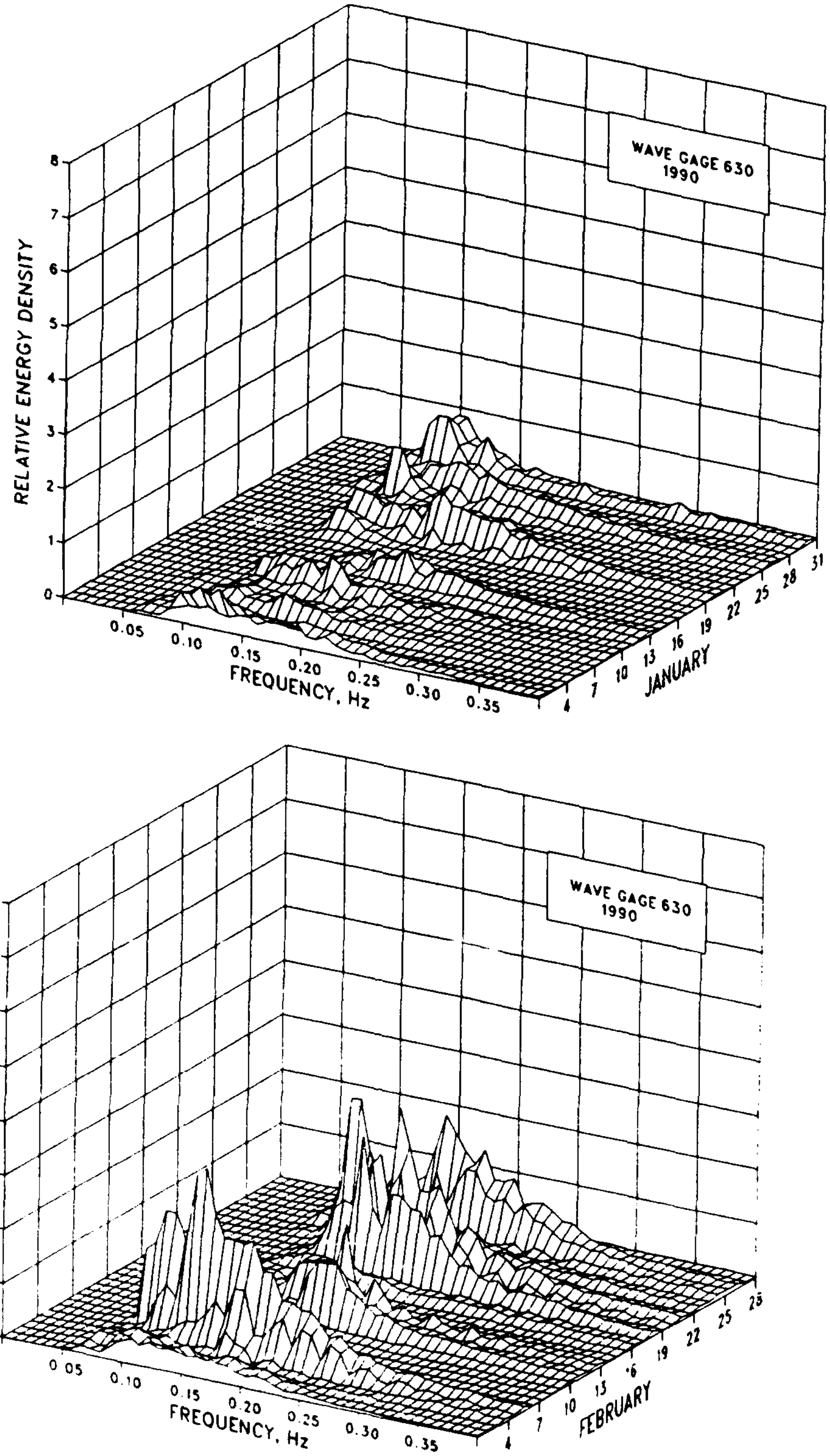
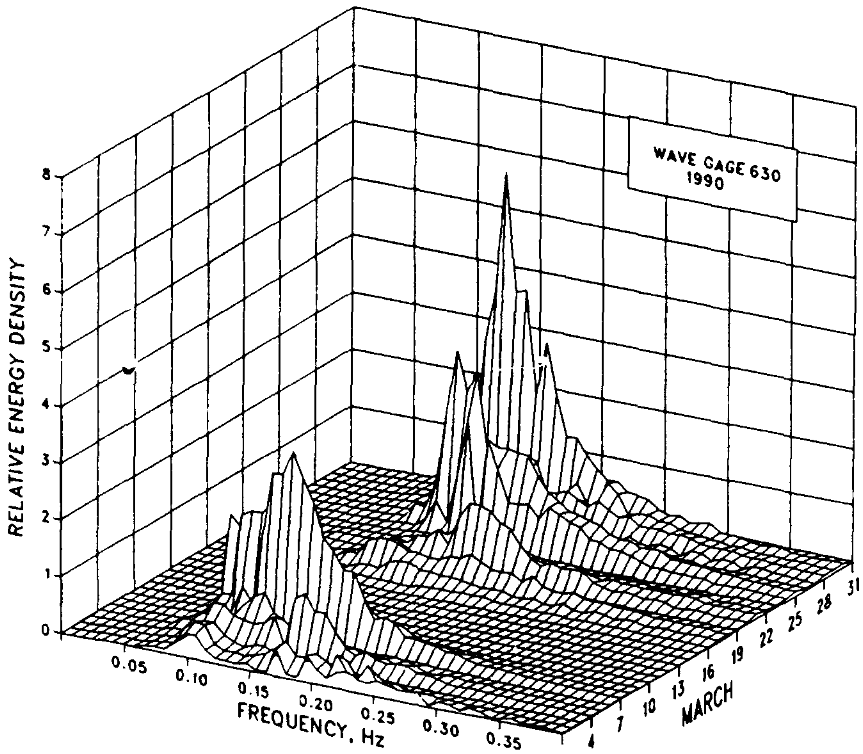


Figure B8. 1990 monthly spectra for Gage 630
(Sheet 1 of 6)



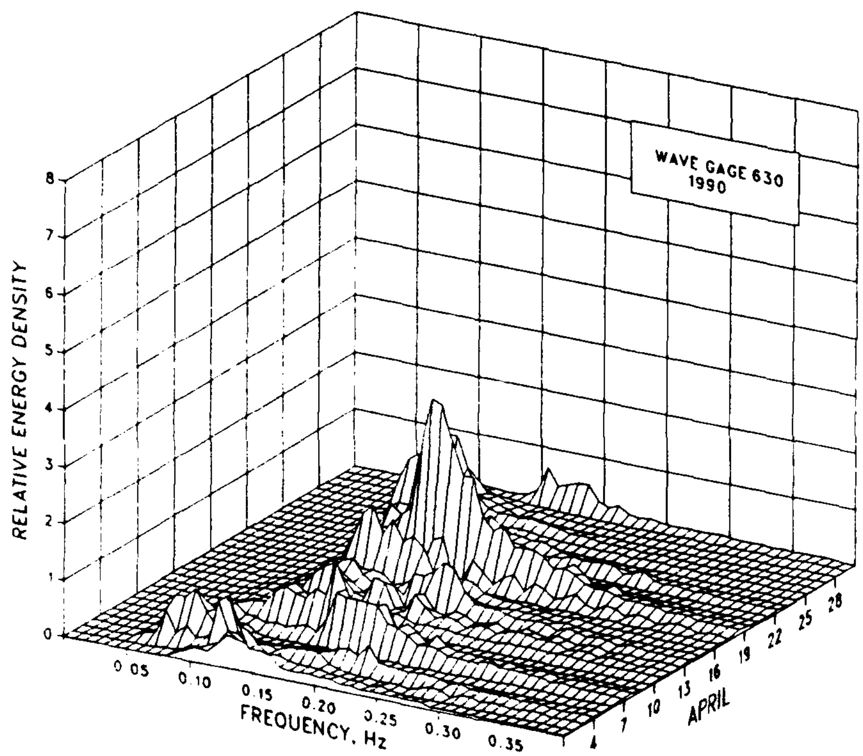
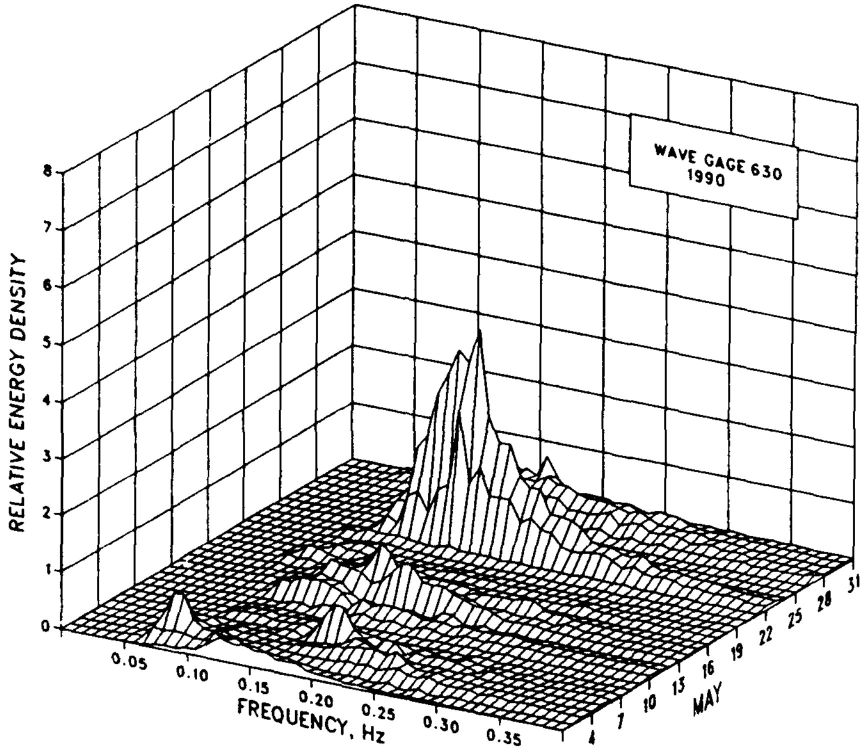


Figure B8. (Sheet 2 of 6)



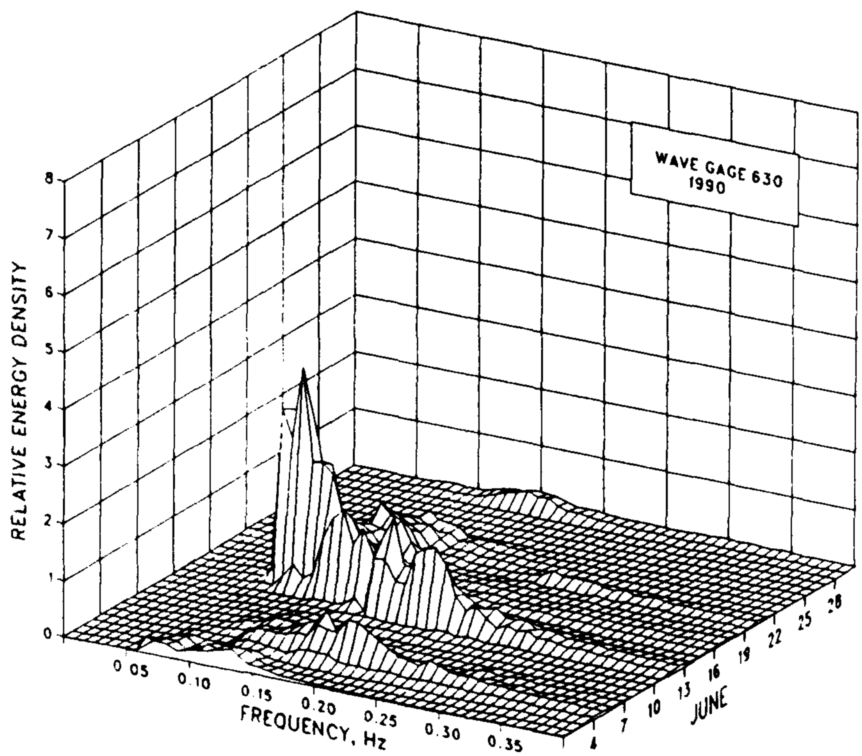
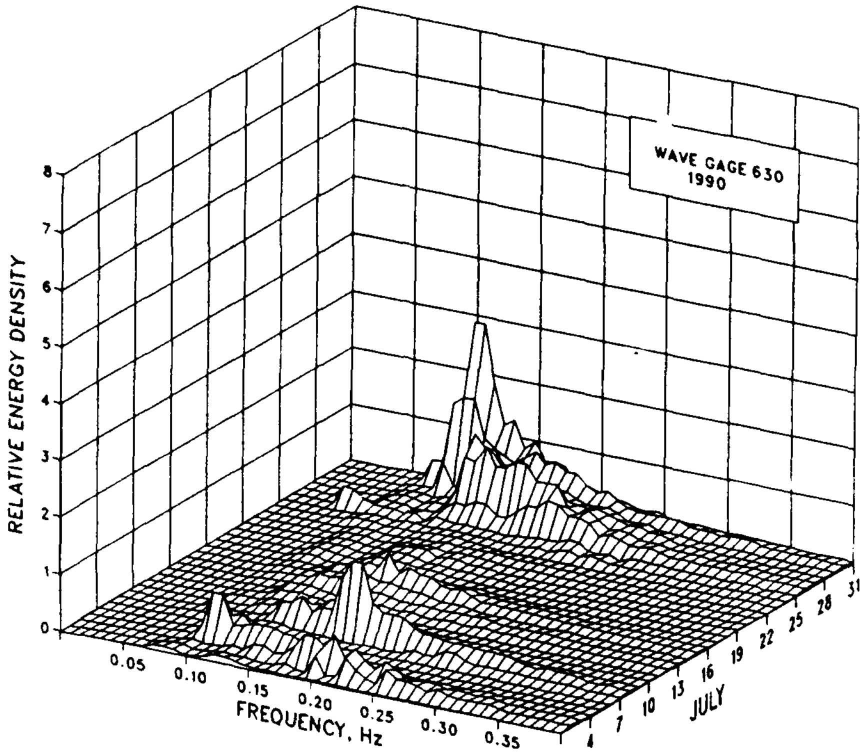


Figure B8. (Sheet 3 of 6)



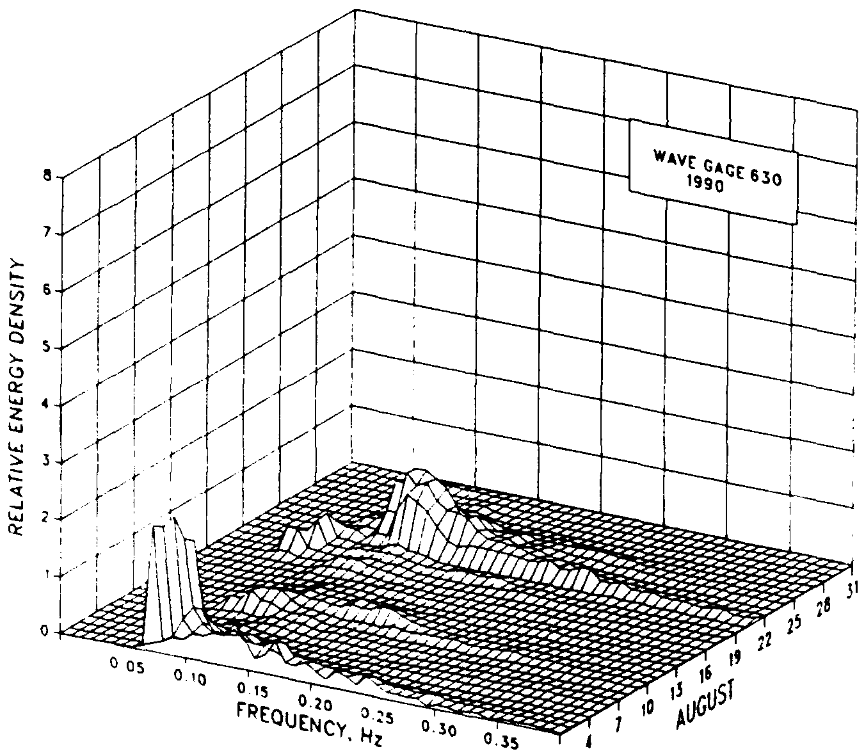
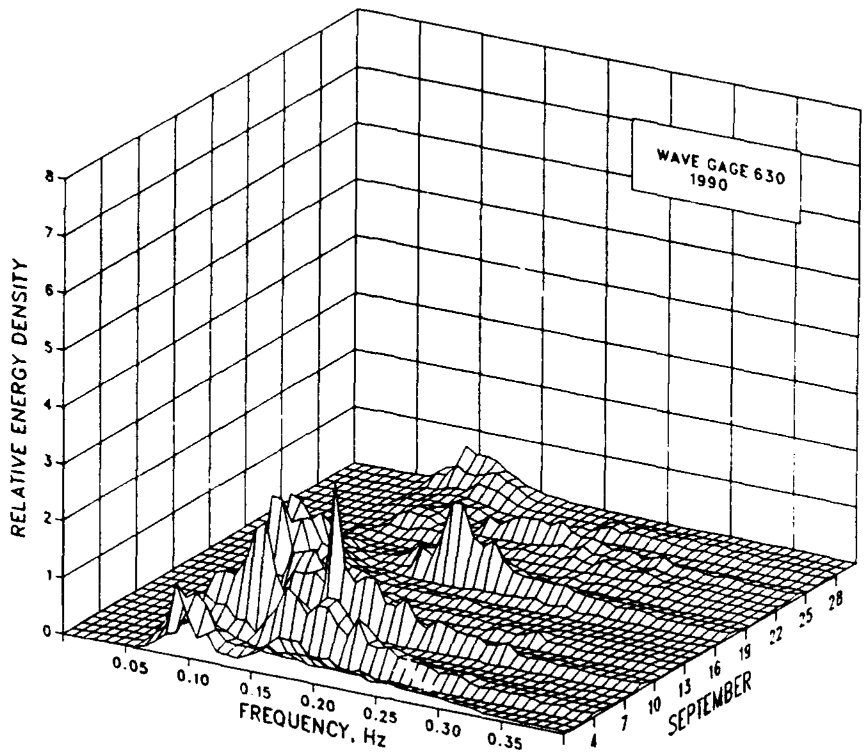


Figure B8. (Sheet 4 of 6)



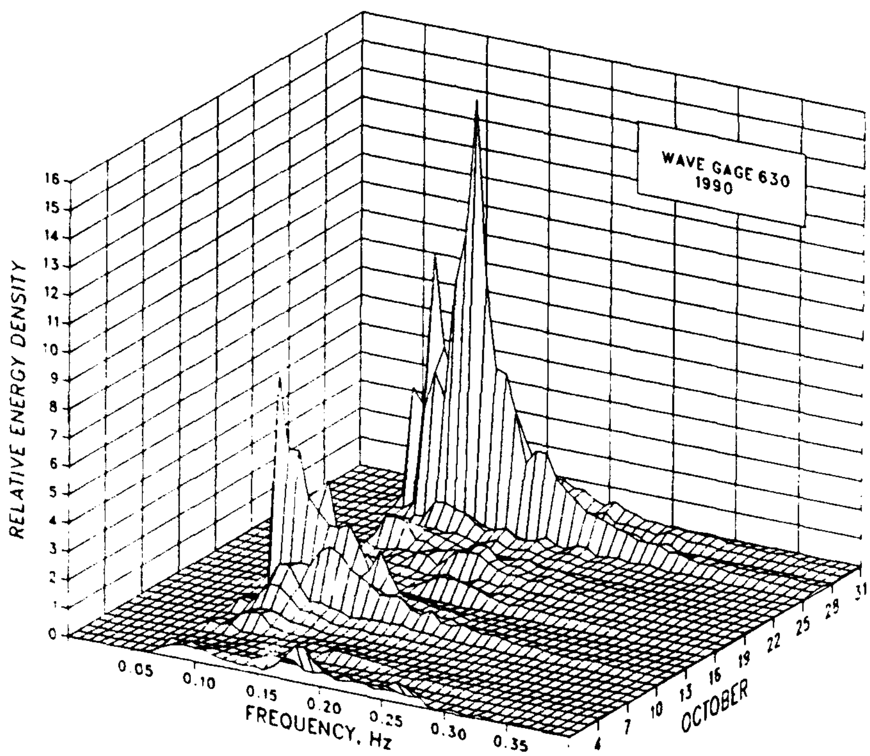
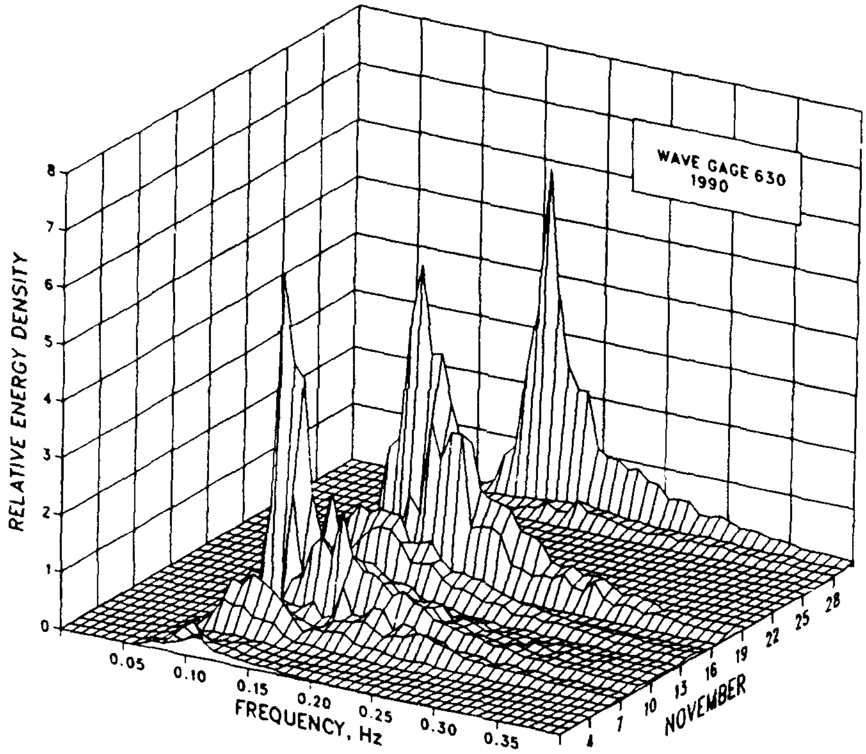


Figure B8. (Sheet 5 of 6)



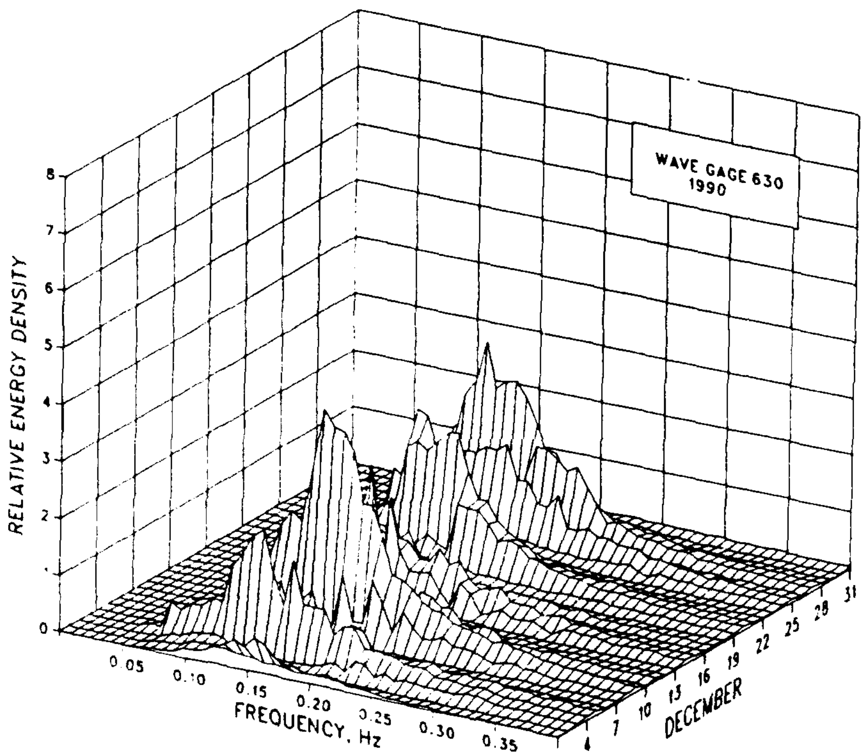
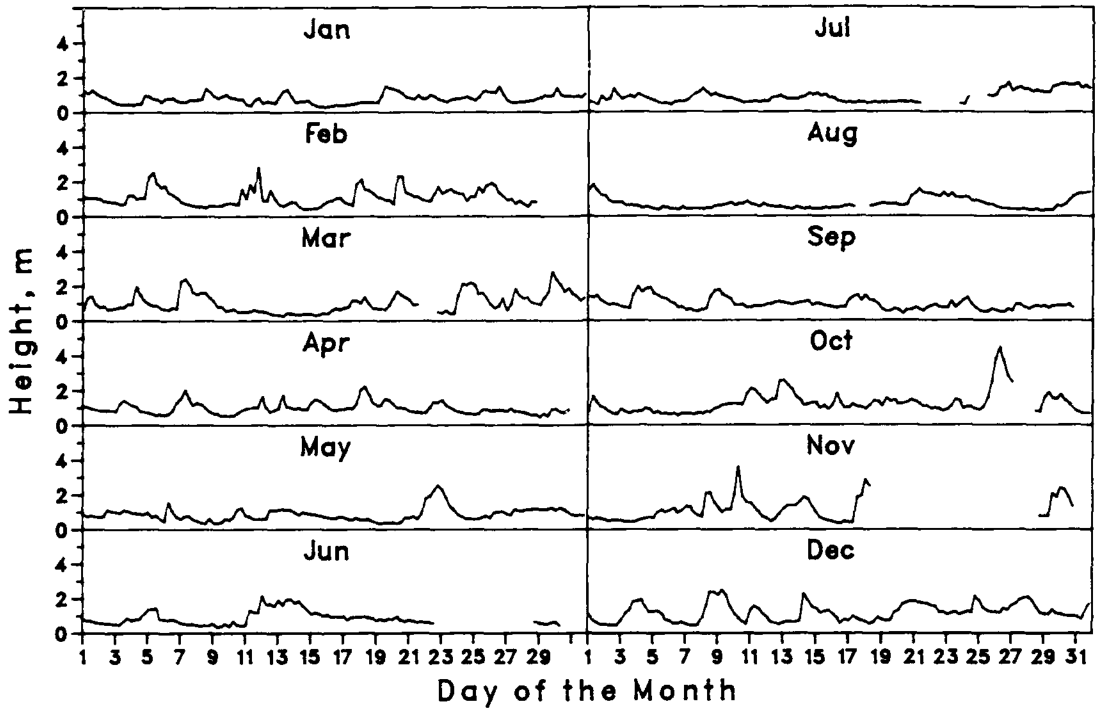


Figure B8. (Sheet 6 of 6)

Table B7

Wave Statistics for Gage 630

	1990							1980-1990						
	Height				Period			Height				Period		
Month	Mean m	Std. Dev. m	Extreme m	Date	Mean sec	Std. Dev. sec	Number Obs.	Mean m	Std. Dev. m	Extreme m	Date	Mean sec	Std. Dev. sec	Number Obs.
Jan	0.8	0.3	1.5	19	8.3	2.2	123	1.2	0.7	4.5	1983	8.1	2.7	1194
Feb	1.1	0.5	2.8	11	8.3	2.5	111	1.2	0.7	5.1	1987	8.4	2.6	1121
Mar	1.1	0.6	2.8	29	8.8	2.7	119	1.2	0.7	4.7	1983	8.6	2.6	1240
Apr	1.0	0.4	2.2	18	8.9	2.3	115	1.0	0.6	5.0	1988	8.6	2.7	1207
May	0.9	0.4	2.5	22	8.1	2.6	124	0.9	0.5	3.3	1986	8.1	2.4	1229
Jun	0.9	0.5	2.1	12	8.1	2.2	93	0.8	0.4	2.4	1988	7.8	2.2	1138
Jul	0.9	0.4	1.7	26	7.7	1.8	107	0.7	0.3	2.1	1985	8.1	2.5	1164
Aug	0.7	0.4	1.8	1	9.7	2.8	119	0.8	0.5	3.6	1981	8.2	2.5	1180
Sep	1.0	0.4	2.0	4	8.8	3.1	120	1.1	0.6	6.1	1985	8.6	2.7	1191
Oct	1.3	0.7	4.4	26	8.5	2.5	117	1.2	0.7	4.4	1990	8.7	2.8	1239
Nov	1.1	0.7	3.6	10	7.8	2.2	79	1.1	0.7	4.1	1981	7.9	2.7	1037
Dec	1.2	0.6	2.5	9	8.0	2.4	121	1.2	0.8	5.6	1980	8.2	2.9	1067
Annual	1.0	0.5	4.4	Oct	8.5	2.5	1348	1.0	0.6	6.1	Sep 1985	8.3	2.6	14007



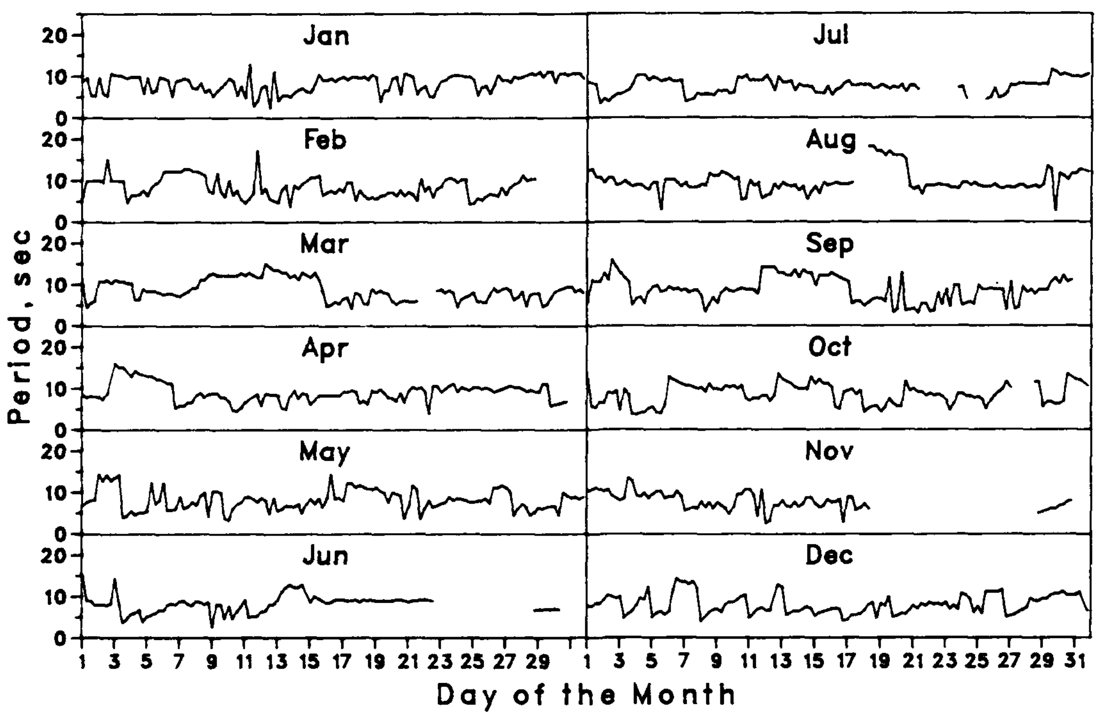


Figure B9. Time-histories of wave height and period for Gage 630